The Journal of the Indian Botanical Society
(Formerly "The Journal of Indian Botany")

VOL. XXIX] FEBRUARY, 1950 [No. 1

PALAEOBOTANY IN INDIA—VII

PROFESSOR BIRBAL SAHNI, F.R.S.

1891—1949.

Professor Birbal Sahni was born at Bhera in Shahpur district, West Punjab on the 14th November, 1891. The town of his birth, situated near that field museum of geology, the Salt Range, has been the home of several distinguished families of the Punjab. The Sahnis were prominent businessmen at Bhera, and his grand-father, Lala Karam Chand Sahni owned a flourishing banking concern at Dera Ismail Khan. Lala Karam Chand's hobby was his experiments in alchemy, which he practised in company of a venerable muslim friend, purely for the fun they provided them. Birbal Sahni was the second son of Lala Ruchi Ram Sahni, who retired in 1918 as Professor of Chemistry at the Government College, Lahore, and Shrimati Ishwari Devi. The father was a well known figure in the educational circles of the province, a profound scholar, and a pioneer in the field of social reform. Birbal Sahni received his early education at home under the benevolent care of his father. Even as a child he was attracted towards nature and used to spend long hours collecting specimens of leaves, shells, rocks, etc. His father, recognising the boy's bent of mind, gave him every encouragement in these pursuits. During vacations he used to take him for long treks in the Himalayas, which afforded his son the fullest opportunity of indulging in his favourite pastime. This frequent and intimate contact with nature from an early age was perhaps responsible for Professor Sahni's extraordinary powers of observation that enabled him to perceive details easily missed by others. The love of trekking in the Himalayas, acquired during his childhood, persisted in Professor Sahni throughout his life. Before he left for Cambridge in 1911 he had been as far as the Tibetan border and had met there the famous Swedish explorer, Sven Hedin. Later he made many trips on foot, alone or in company of his wife and of Professor Shiv Ram Kashyap of Lahore, between Jammu and Srinagar and to Amarnath, Kargil, and Leh.

When he had completed his studies at Lahore at the Central Model School, Sahni joined the Government College where he studied botany under Professor Kashyap, the foremost Indian botanist of his time. He took his B.Sc. from the University of Punjab in 1911. The same

year he proceeded to England and entered the Emmanuel College at Cambridge as an undergraduate. Here, after obtaining his tripos in natural sciences, he became a research scholar under Sir A. C. Seward, and was with him throughout the years of the first world war. The celebrated palaeobotanist found in him a very promising and devoted pupil and regarded him with great affection. The years at Cambridge cemented between the two the bonds of a close friendship which endured throughout their lives. Professor Sahni had a distinguished record at Cambridge, was a founder scholar, exhibitioner, and winner of the Sudbury Hardyman Prize. During this period he had also attended summer semesters at Munich under Professor K. Goebel and taken a B.Sc. from the University of London. Working under Seward, he was awarded the Doctorate in Science of the London University in 1919, and in 1929 he was conferred the Sc. D. of Cambridge.

On his return to India in 1919 he held successively for one academic year the chair of botany at the Universities of Banaras and Punjab. In 1920 he married Savitri Suri, younger daughter of Mr. Sunder Das Suri, Inspector of Schools, Punjab. On her, his life long partner and co-founder of the Institute of Palaeobotany, now falls the heavy burden of fostering the young Institute. In 1921 he was appointed Professor of Botany at the University of Lucknow and in 1933 was elected the Dean of the Science Faculty. Both these offices he held till the time of his tragic passing away.

At Lucknow Professor Sahni's name began to attract students from all parts of India. The early years at the university were of tremendous activity for him. He kept late hours in the laboratory, and it was quite usual for him to come back to it after dinner and continue his work till the small hours of the morning. Here assisted by Mrs. Sahni he would do his own cutting and grinding of fossils, sketching, and photographic work. Between 1920 and 1926 he never had any vacation but spent the summer months studying in the plant fossil galleries of the Geological Survey of India, Calcutta. A tireless worker himself, he expected both from colleagues and students the highest degree of efficiency. Few heads of department give so much individual attention to junior students as he used to devote. For post-graduate scholars his stress was not on mere book knowledge, but on the development of their own faculties of observation and criticism. He never encouraged in them the attitude which takes things too readily for granted.

Though primarily a palaeobotanist, much of Professor Sahni's earlier work was concerned with living plants. Between 1915 and 1936 came out many important contributions on the morphology and evolutionary trends of pteridophyta and gymnosperms, e.g., *Nephrolepis*, *Tmesipteris*, *Acmopyle*, *Taxus*, *Cepholotaxus*, *Dacrydium*, *Fitzroya*, *Ginkgo*. Several of these papers dealt with questions of great theoretical significance as is shown by the titles, "Observations on the Evolution of Branching in Filicales" (1917), "Modern Psilotaceae and Archaric Terrestrial plants" (1923), and "The Ontogeny of Vascular plants and Theory of Recepitulation" (1925). In 1919, while still at Cambridge, he revised and adopted for purposes of Indian students Lawson's text book of botany.

The study of fossil plants in India in the present century owes its progress entirely to Professor Sahni. It is impossible here to give anything but the barest outline of his vast and invaluable contribution. In 1918 was published the first of the series of his notable researches on the Zygopterideae. About this time he had also begun, in collaboration with Professor Seward, the important task of revising the Indian Gondwana plants. This was published in the *Palaeontologia Indica* in 1920, and in the same journal appeared in 1928 and 1930 his exhaustive work on the Indian fossil conifers. Between 1918 and 1949 Professor Sahni had published a large number of papers dealing with nearly every aspect of fossil botany. Besides describing a large quantity of fossil material from India and other countries he contributed important observations on the related palaeographical and geological questions, such as Permo-Carboniferous life provinces, Wegener's theory of continental drift, Himalayan uplift, and the eastward opening of the Himalayan geocyncline. In 1939, with a view to co-ordinate research in fossil botany by workers spread in different parts of the country he started the research bulletin, " Palaeobotany in India ", with himself as its editor.

The fossiliferous areas in India to which Professor Sahni devoted special attention were the Rajmahal hills of Behar, the Deccan Intertrappean Series, and the Salt Range of Punjab, which now forms a part of Pakistan. The Rajmahal hills have been a favourite hunting ground for Indian palaeobotanists. Professor Sahni described from here such interesting and important types as *Homoxylon rajmahalense*, *Rajmahalia paradoxa*, and *Williamsonia Sewardiana ;* his most remarkable discovery, however, was the Pentoxyleae, fossil plants for which a new group of gymnosperms was proposed by him, and which he was busy further investigating during his last days. We paid what proved to be our last visit in his company to Nipania, the locality of the Pentoxyleae in January 1949. It was perhaps a presentiment that made him very reluctant to leave the place, even after we had collected much more material than was possible for us to carry and the porters were almost groaning under their loads. When, at last, the rest of us withdrew in sheer fatigue he still lingered on, in spite of his indisposition, shifting and breaking the heavy and hard silicified blocks. He wanted to collect more.

One of Sahni's valuable contributions was the bringing of plant fossils to the aid of problems of stratigraphy, in solving disputes concerning the age of Indian sedimentary strata and in the measurement of geological time. In two cases namely, those of the age of the Deccan Traps and the Saline Series of the Salt Range his results upset the prevalent views of the geologists based on the field evidence. The rich and beautifully preserved flora of the Deccan Intertrappean beds which he worked out comprised palms, charophyta, water ferns, and seeds and fruits of angiosperms along with a host of other interesting types. The very interesting and important discoveries made by him here were by themselves ample reward for a palaeobotanist's labours; but they also proved beyond doubt a Tertiary age for the Deccan lavas against the Cretaceous age ascribed to them by the geologists. The Saline Series controversy is fresh in the minds of palaeobotanists and geologists. Here also the steadily accumulating mass of microfossils evidence went in favour

of a Tertiary view as opposed to the Cambrian or pre-Cambrian suggested by the field data. He was always at pains to emphasise the fact, which is often ignored, that between the testimony of the rocks and the testimony of plant fossil there could be no real conflict. Latterly, he had begun to concentrate a good deal of his attention on the utilisation of microfossil studies for purposes of economic geology, such as the correlation problems connected with the quest for coal and oil.

Professor Sahni was twice President of the Botany Section of the Indian Science Congress (1921, and 1938, the Silver Jubilee session). In 1926 he presided over the Geology Section, and in 1940, the Madras session, ~~he was the~~ General President. No better and more comprehensive insight into the problems of Indian palaeobotany can be had than by the perusal of his masterly addresses delivered on these occasions. There are not many scientists in the country who could rival his literary style, which combined with the precision of scientific reasoning an ease and distinctive grace of its own. He was also most effective as a speaker and his cultured voice always commanded the rapt attention of an audience. In spite of his busy life as a palaeobotanist and his heavy teaching and administrative duties, Professor Sahni found time to devote to other subjects. He took considerable interest in archaeological studies, and was awarded in 1945 the Nelson Wright Medal of the Numismatic Society of India for a paper on the technique of casting coins in ancient India. He was an enthusiastic clay modeller and collector of stamps.

In 1936 Professor Sahni was elected to the Royal Society, the fifth Indian at that time be thus honoured. He was also a Fellow of the Geological Society, and a Foreign Honorary Member of the American Academy of Arts and Sciences. Shortly before his passing away he had been elected the Honorary President of the International Botanical Congress to be held in Stockholm in 1950. Before this he had been the Vice-President of the Botany Section at the meetings of the Congress at Cambridge (1930) and Amsterdam (1935). He was honoured by the Fellowship of most of the Indian learned Societies and was the Honorary Professor of Botany at the Banaras Hindu University. He was twice President of the National Academy of Sciences, one of the founders and President of the Indian Botanical Society, and Vice-President of the Indian Academy and the National Institute of Sciences of India. The Royal Asiatic Society of Bengal awarded him the Barclay Medal for outstanding researches in biological sciences, and he was the recipient of Sir C. R. Reddy National Prize for 1947 in natural sciences. He was conferred the honorary D.Sc. by the Universities of Patna and Allahabad.

Professor Sahni's personal qualities won for him universal esteem. He was loved and respected in his own country not only as a scientist of outstanding merit but also as a great patriot. His nationalism, however, was not confined to the political variety ; it embodied a deep love for the great cultural heritage of his country. This love for India and things Indian was reflected alike in his dress and in the profound understanding he had of our aesthetic and artistic traditions. No one who came in contact with him could fail to be struck with the gentleness and refinement of his manner, his innate kindness, and the nobility of his bearing.

In society Professor Sahni was always genial. He had a fine sense of humour, and those who had the good fortune of accompanying him on excursions will always remember his unfailing repertoire of anecdotes and tricks with which he used to entertain the party.

During his last six or seven years Professor Sahni's energies were focussed on the creation of the Institute of Palaeobotany. The Institute personified his life's ambition, the culmination of his scientific activity for nearly three decades. It was his aim to make it an international centre for research in fossil botany. His dream was partially fulfilled with its coming into existence in June 1946, and with the laying of the foundation stone of its new building by Pandit Jawaharlal Nehru on the 3rd April 1949. But the Institute brought in its trail unexpected worries and additional heavy duties for him. Work had always been for Professor Sahni his greatest pleasure, and he was never in the habit of sparing himself where this was concerned. Sir C. V. Raman, once described him as a " restless spirit ". Perhaps no epithet can sum up his personality better than this, and he took to his increased burden of work with even greater enthusiasm. His health, however, began to show the strain which the manifold duties at the university and the newly founded Institute imposed upon him. But as was his wont he continued to overwork, ignoring the warnings of nature and the entreaties of those near him. He had a severe heart attack on the evening of Friday, the 8th April and breathed his last on the 10th at 12-5 a.m., only a week after the foundation stone ceremony of the Institute's new building took place. By his passing Science has lost one of its greatest votaries, and India a brilliant son. To Palaeobotany in India his loss is an irreparable one. But he has left behind a great and a worthy example and the highest traditions. May these be an everlasting incentive for greater and greater effort on our part to serve the cause for which he had dedicated his life.

R. V. SITHOLEY

PALAEOBOTANY IN INDIA

A Bulletin of Current Research

(*Published with the co-operation of a Committee*)

VII

(*Received for publication on October* 5, 1949).

The present number combines our reports for 1947 and 1948. We regret that circumstances have again prevented our bringing them out in time. We are grateful to the Editorial Board of the Journal of the Indian Botanical Society and especially to its Chief Editor, Professor G. P. Majumdar, for the space they continue to provide us in the columns of their journal, in spite of the increased difficulties and cost of printing.

(MRS.) SAVITRI SAHNI,
Convenor.

BIRBAL SAHNI INSTITUTE OF PALAEOBOTANY
UNIVERSITY ROAD,
LUCKNOW.
28*th September* 1949.

R. V. SITHOLEY,
Secretary and *Editor.*

CONTENTS

(*Papers published in full are only briefly noticed, and are marked with an asterisk.*

PRE-CAMBRIAN AND CAMBRIAN

United Provinces, Mirzapur district—*Search for organic remains in Vindhyan rocks.* Specimens of Vindhyan limestone and carbonaceous shale were examined for traces of early plant life. Neither macerations nor ground-sections of the matrix have so far revealed any organic remains.

K. JACOB

Punjab, Salt Range—*Problems of Salt Range geology: are the salt pseudomorph beds of Tertiary age?* A. K. Ghosh and A. Bose have shown (*Nature, 1947*, **160**, *p. 796*) that the salt pseudomorph beds in the Salt Range contain a microflora essentially of the Saline series type. This microflora, according to them, suggests a Tertiary age for the salt pseudomorph beds. It is probably the first time that the Palaeozoic age of these beds has been questioned; and if it is proved beyond doubt that they contain angiosperm remains *in situ*, the geological implications of the

discovery would be far reaching. The salt pseudomorph beds form the top of the Cambrian sequence in the Salt Range. From all recent accounts it is evident that they overlie the magnesian sandstone with complete conformity, while they are themselves succeeded unconformably by the Talchir boulder bed. If the salt pseudomorph beds are Tertiary, then (*i*) there must be an important unconformity with a big time gap (Cambrian—Tertiary) between these beds and the magnesian sandstone ; and (*ii*) the junction with the overlying Talchir boulder bed must be a tectonic contact, involving an overthrust of Carboniferous on Tertiary. There is nothing inherently improbable about the existence of these features in such a highly disturbed area : in fact both of them are parallelled within the Salt Range. North of Jalalpur we see the Miocene Kamlial beds overlie the Neobolus shales, while at Chittidil the Talchir boulder bed is seen thrust over the Eocene saline series.

A careful search for microfossils has been made in the following six samples from the salt pseudomorph beds. Full precautions against contamination were taken, though one can never assert that all possibilities of contamination have been eliminated.

S 12—a light chocolate, sandy shale with well formed pseudomorphs, collected from the Pidh road section near Khewra.

S 84—a light maroon, compact shale with pseudomorphs, from near Mitha Patan, Khewra gorge.

S 62 (*SRE 109*)—a soft, light chocolate coloured shale from a ravine north-east of Chittidil.

S 63—shale with crude lamination, looking more like a sandstone, from near Chittidil.

Kindly sent by Ghosh.

(*57/285* (*SRE 46*)—" A clayey sandstone from the salt pseudomorph beds, 3/4 mile N.E. of Chittidil rest house ".

G 2—" Dolomite in basal part of salt pseudomorph beds, Chittidil ".

Ghosh and his co-workers claim to have found in the Salt pseudomorph beds (*loc. cit.* and *1948*, *Proc. 35th Ind. Sci. Cong. Patna, p. 145*) a microflora representing all the groups of vascular plants, namely, pteridophyta, gymnosperms, and angiosperms. We have examined a large number of permanent slides prepared from each of the above samples, and our findings are comparatively very meagre. There are in all about 10 types of micro-remains recovered : (1) slender structureless fibres (not vascular), (2) fungal hyphae, (3) pieces of septate filaments, (4) rhizoid-like structures, (5) a boat-shaped body recalling an ascus, (6) structureless membranes, (7) chitinous fragments, (8) an egg-like body, (9) a multicellular structure with four septate appendages at one end, and (10) three tiny fragments whose structure is not characteristic enough for their inclusion in the category of woods. There is nothing among these finds which can with certainty be assigned to vascular plants.

For our part we have been accustomed to regard the salt pseudomorph beds as of early Palaeozoic age. Our results so far do not corroborate those obtained by Ghose and his associates. Therefore, until

more convincing evidence is forthcoming, we cannot express any opinion in contradiction to the already established Cambrian age of these beds.

B. SAHNI, R. N. LAKHANPAL, and
D. C. BHARDWAJ

Punjab, Salt Range—*Microfossil investigation of the magnesian sandstone.* The Neobolus beds of the Cambrian sequence in the Salt Range are conformably succeeded by the magnesian sandstone stage. The Neobolus beds contain Cambrian branchiopods and trilobites, and in the magnesian sandstone is found *Stenotheca*, a mollusc of lower Cambrian age. The recent discovery in the latter by A. Ghosh, J. Sen and A. Bose (*1948, Proc. Ind. Sci. Cong., p. 145*) of carbonised wood bearing uni-to multiseriate bordered pits, therefore, came as a surprise. To check the results of these authors I carefully searched a sample of the magnesian sandstone for microfossils. Pieces from this sample (S. 4), collected from the circuit house hill, Khewra, were macerated separately in dilute HC1 and HF. From the examination of more than 50 slides no microfossils were recovered.

D. C. BHARDWAJ

Punjab, Salt Range—**Search for microfossils in the purple sandstone, Khewra gorge. Second symposium on the age of the saline series in the Salt Range, Punjab. Proc. Nat. Acad. Sci. Ind.* **16** (*2-4*) *: 92-94. 1946.* (*Issued 1947*).

J. HSÜ

DEVONIAN

China, Central Yunnan—**Plant fragments from Devonian beds in Central Yunnan, China. Jour. Ind. Bot. Soc. Iyengar Comm. Vol., pp. 339-360. 1946.* (*Issued 1947*). *With 5 plates, 5 text-figs., and 1 map.*

J. HSÜ

China, Central Yunnan—*Cuticles and spores in a brown shale from Lunan.* This work is based on preparations made from a brown shale found in Ta-Tsun, Lunan district (24° 7′ : 103° 3′). Several kinds of stem cuticles with stomata have been obtained. Three of these cuticle types show structure which cannot be compared with those of any known plants. The cuticle of the fourth type resembles to some extent that of *Drepanophycus spinaeformis* Goeppert. The fifth type is in the form of a tube which encloses tracheids with scalariform thickenings ; on the tube are scattered stomata of unknown affinity. No spines or leaves are associated with these cuticles.

Thirty-four types of spores and one spore-like body were obtained. Most of them possess a triradiate mark. Four of these types are megaspores of lycopods, three are probably isospores of lycopods ; one type has possibly Calamarian affinity, and the rest are probably microspores or isospores of other groups of pteridophytes. The dominance of heterosporous lycopods in the Lunan flora and the complete absence in it of gymnosperms suggest that the beds cannot be older than middle Devonian. They are definitely younger than the Devonian beds of Po'shi.

J. HSÜ

CARBONIFEROUS

Scotland, calciferous sandstone series, Pettycur—*Morphology of Botryopteris antiqua and Stauropteris burntislandica.* The main part of this investigation was carried out at the Botany School, Cambridge, but further work on these species is being continued at Lucknow.

Botryopteris antiqua.—Our knowledge of this species has to be revised in the light of new evidence. Benson (*1911*, *Ann. Bot.* **25**) found that a radial stem of *B. antiqua* alternately produces two types of petioles, monarch and diarch. I have, however, found that *B. antiqua* possesses two types of stem, radial and dorsiventral, and only one type petiole, viz., monarch. A petiole which Benson called diarch is, in fact, a dorsiventral stem of the plant which acted like a trailing organ and gave out radial stems at intervals. The latter bore roots and monarch petioles in quick spiral succession. A dorsiventral stem looks like a petiole, but is much bigger in size and differs from the latter in minute details of the structure.

A part of the lateral branching of the petioles has also been traced in serial sections. A petiole gives off branches alternately, which in their turn produce branches in the same manner. Such branching is repeated upto the VI order, when an ultimate branchlet measuring only 0·2 mm. is reached. The ultimate branchlet simply ends by tapering slightly. The size and structure of all the branches and at what distance they branched were noted. From these data a part of the so called frond was reconstructed which looked sometoing like *Rhodea Smithi*. *B. antiqua* does not possess a flattened lamina, but cylindrical branchlets arranged in sucn a way as to look like a " frond ".

I have not been able to find a definite connection between an ultimate branchlet and multiseriate sporangium attributed to *B. antiqua*. Most probably a sporangium is attached singly to a branchlet and not in groups of four as suggested by Scott. Further work on the sporangium as revealed in serial sections is in progress.

It may be recorded here that the upper Carboniferous species, *B. ramosa* shows the same habit as *B. antiqua* and *B. hirsuta*. *B. ramosa* also possesses a dorsiventral stem which gives rise to radial stem. From the examination of Scott's slides kept in the British Museum, it appears that the leaf trace *lt* 1 shown in Fig. 150 in his " Studies " (*1920*, *p. 339*) is really a dorsiventral stem from which the radial stem giving out roots and leaf trace *lt* 2 has arisen. Thus *B. antiqua*, *B. hirsuta* and *B. ramosa* from a connected series and show progressive evolution.

Stauropteris burntislandica.—The rhizome of this species is still unknown, but its serial branches have been traced upto the minute tips. A rachis or the main shaft of the " frond " gives out lateral branches upto the VII order. Aerial axes of various sizes, ranging from 2 mm. to 0·08 mm. were present in the material ; they were traced in close serial sections, their divisions were observed and the sizes measured. The axis of the I order (or rachis) is 2 mm. in diameter. It is observed to give out two pairs of alternate branches (II order), 1·6—1·4 mm. in size, at a distance of 4·5 cm. They have X-shaped tetrarch stele. The axes of the II order are also tetrarch and produce pairs of branches (III order) 1—1·1 mm. in size, which in their turn again give out pairs of branches

(IV order) 0·64 mm. in size. The axis of the VI order is tetrarch with triangular stele, but produces two alternate pairs of monarch branches (V order), 0·32—0·24 mm. in diameter, and is itself reduced to monarch condition. An axis of 0·32 mm. gives out a single branch 0·24 mm. in diameter, which immediately bifurcates into 0·16 mm. axes (VI order). 0·16 mm. is the size of the penultimate branch which ends by simple forking, each fork measuring 0·1 to 0·08 mm. in diameter.

This provided a complete lateral branching of the "frond" of *Stauropteris*. From these results a part of the frond was re-constructed, which looked something like *Rhodea tenuis*. There is no indication of flattening or dorsiventrality in the ultimate branchlets, but the whole branch system, which is highly divided, gives an appearance of the "frond".

Sporangia (which I have called microsporangia) similar to those of *S. Oldhamia*, are found in association with branchlets of *Stauropteris burntislandica*. The microspore has a smooth wall and a triradiate mark and measures 0·03 mm. in size.

Mrs. Scott referred some spindle shaped bodies, *Bensonites fusiformis* as glands of *S. burntislandica*. It is shown that *Bensonites* is not a gland, but a *megasporangium* attached to the ultimate branchlet of *S. burntislandica* "frond" (pl. 1, fig. 3). The lower part of the sporangium is sterile and is provided with a vascular strand, while the upper chamber contains spores. One such well preserved spore is shown in fig. 3. Small bits of exine, some showing distinct triradiate marks, are seen in most of the specimens. The spore is comparatively big and measures 0·16 mm. *Bensonites* strongly recalls Halle's *Sporogonites* from the lower Devonian. Further work on *Bensonites* is in progress.

S. burntislandica is a heterosporous plant and is interesting as a synthetic genus. It shows certain similarities to the Psilophytales on the one hand and the Zygopterideae on the other. Morphologically *S. burntislandica*, together with *Archaeopteris* which also shows heterospory, may stand between the Psilophytales and Pteridospermae.

I believe *Stauropteris* deserves a separate order of its own, which, perhaps, together with the Zygopterideae sprung up from the common ancestor, the Psilophytales, but separated early from Zygopterideae probably in the direction of Pteridospermae.

K. R. SURANGE

PERMO—CARBONIFEROUS

Punjab, Salt Range—*Microfossils from the Talchir boulder bed.* During his excursions to the Salt Range in October 1945 and November 1946, B. Sahni collected a number of samples from the Talchir boulder bed. Out of these he selected two, S65A and S65B for microfossil examination. The locality of these is east of Chittidil rest house, about a mile S.E. of Serai village. He recovered from S65A a well preserved coniferous wood ; and from S65B a dark, smooth-walled ellipsoid spore and a coniferous wood (*1947*, *Proc. Nat. Acad. Sci. Ind.* **16** (*2-4*), *p. 18*).

In July 1947 he kindly passed on the above samples to me for further examination. Small pieces of the matrix were carefully macerated in 12 per cent HCl. The microfossil examination revealed a large number of fragments of coniferous wood, a few pieces of cuticle, and bits of a chitinous membrane with numerous sockets for setae. Samples from the Talchir boulder bed in other localities of the Salt Range were also macerated. The majority of them contain remains of coniferous wood and a large number of chitin pieces. Sample S 96 from the Pidh road, about five miles from Khewra, has yielded a large number of spores. Most of these spores appear to belong to the group trilobata of Naumova.

M. N. Bose

Orrisa, Talchir.—*Microfossils in a micaceous shale from the Talchir coalfield.* The material (exact horizon not known) was collected by B. Sahni and Jen Hsü. A large number of microfossils were obtained by maceration. They comprise of cuticle and wood fragments, microspores, and a number of megaspores. The occurrence of the megaspore types is interesting.

D. D. Pant

Australia, Bacchus Marsh (Victoria).—*On the occurrence of Pityosporites Seward in a lower Gondwana tillite of Australia and its possible relationship with Glossopteris.* Disaccate pollen grains of the *Pityosporites* type (some of them with a striped body) have been found in a piece of tillite from Bacchus Marsh, along with many other spore types which are essentially similar to those reported from the lower Gondwana rocks of India and Australia.

Species of *Pityosporites* with a similar striped body are constantly found in association with *Glossopteris Browniana* and *G. communis.* The present discovery of disaccate pollen in the Bacchus Marsh tillite therefore suggests that *Glossopteris* probably existed in the ice age.

D. D. Pant

[1] **Australia, Kamilaroi.**—*Plant fossils from Kamilaroi, Australia.* A collection of Kamilaroi plants, kindly loaned by the Director, National Museum, Sydney, is being worked out, especially with regard to their cuticular structure. The specimens include species of *Glossopteris, Gangamopteris, Noeggerathiopsis,* "*Zeugophyllites*" and *Brachyphyllum.*

K. Jacob

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[1] This and the following notes by K. Jacob are based on the report kindly supplied by the Director, Geological Survey of India, Calcutta. (See *Rec. Geol. Surv. Ind.* **81** (1) : 195-201).

PERMIAN

Central India, south Rewah—*On a new species of Phyllotheca (P. striata) from the south Rewah Gondwana basin, and its comparison with P. Etheridgei Arber from the New Castle series, New South Wales, Australia.* A brief note on *P. striata* has appeared in "Palæobotany in India"—VI (*p. 245, pl. 12, figs. 4-5*). The original material of *P. Etheridgei* was kindly obtained for me by Sahni from the Australian Museum, Sydney and from the Sedgwick Museum, Cambridge. A careful comparison of the two species has confirmed the view expressed before that the Rewah fossil is a new species. It has now been named *P. striata*. The chief characters of this species are the amplexicaul base of the leaf-sheath with the distal saucer-like spreading disc ; and the prominent tissue, composed of obliquely placed elongated cells giving the appearance of striæ, on both the sides of the thick midrib in each segment of sheath. The leaf sheath comprises of about 22 segments.

P. striata and *P. Etheridgei* show a general resemblance in size and form of the leaf-sheath and in the presence of transverse striations on the sheath segments. They differ in the nature and number of veins in the leaf-sheath (22 in *P. striata*, and 30 or more in *P. Etheridgei*) and in the character and size of the stomata (pl. 1, figs. 1, 2). The presence of striæ in these species of *Phyllotheca* is a very interesting feature. Similar striations have been mentioned in a species of *Annularia* from America by M. K. Elias (1931, *Bull. Uni. Kansas.* **32** (10)).

P. Etheridgei belongs the New Castle series (upper coal measures of Australia) which are generally correlated with the upper Permian. *P. striata* comes from a horizon stated to occur immediately below the Barakar coal seam, and regarded as equivalent to the middle coal measures of Australia. Thus *P. striata* is the older species of the two.

S. D. Saksena

Central India, south Rewah—*Fossil plants from Ganjra Nala in the south Rewah Gondwana basin.* The fossil flora described in this paper has been divided into two parts (1) Impressions and (2) Microfossils. Part 1 describes two new species of *Samaropsis* (*S. johillensis* and *S. ganjrensis*) which are found in association with leaf impressions of *Noeggerathiopsis Hislopi*, several species of *Glossopteris*, and one species of *Gangamopteris*.

Samaropsis johillensis (*Palæobotany in India.—VI, p. 246*) has a sub-oblate, elliptical body, with a short median ridge at its proximal end, and two conical beak-like projections at its distal end ; attached to the body laterally throughout its whole length, and inclined to its axis at an angle of about 60 degrees, are two large spreading wings. The length of the body at its median axis is 1 cm. The total wing-span is about 2·3 cm.

S. ganjrensis has a sub-prolate, elliptical body, with two wings attached all round it except at the distal end. The free ends of the wings are rounded and equal or unequal. They are broader at the distal than at

the proximal end. The median axis is 1·2 cm. and the transverse axis 1 cm. approximately.

The comparison of the cuticle obtained from *Glossopteris indica* with that of *G. communis* has confirmed the observation of Mrs. Jacob that the cuticular structure in the two species is quite distinct.

The cuticle of *N. Hislopi* shows a structure different from that of *Cordaites* figured by Seward and Sahni (*1920*, *Mem. Geol. Sur. Ind.*, *Pal. Ind. N.S.*, **7** (*1*)). On the basis of the cuticular structure, nature of venation, and the geographical distribution it is suggested that *Cordaites* and *Noeggerthiopsis* should be regarded as two distinct genera.

Part 2 deals with a bryophytic sporogonium *Capsulites gondwanensis* gen. et sp. nov. (*Palæobotany in India—VI, p. 246*), a few sporangium-like bodies, fungal spots on the cuticle of *N. Hislopi*, and a few filmentous structures of uncertain affinity. The sporangium-like structures were first met with in the macerated material. Later on they were discovered sticking to a *Glossopteris* impression as well as distributed freely in the shaly matrix. *In situ* each of these bodies appears as an impression of two concentric circles. The outer carbonised portion is dissolved during maceration, but the inner part yields a brown sac-like body having a cellular wall. The sac-like body has one smooth spherical end ; the opposite end is narrower and broken, suggesting the point of attachment of the organ. Their size varies from 2·4 × 3 mm. to 3 × 4 mm. Nothing definite about their affinities can be said at present.

S. D. Saksena

Central India, south Rewah.—*A fossil blue-green alga from the Pali beds, Rewah.* The study of microfossils from these beds previously reported in " Palæobotany in India—V " (*pp. 69-70*) and VI (*p. 245*), and in *Proc. Nat. Acad. Sci. Ind.*, **14** (*4-5*) *: 125-141*, 1944, is being continued. Among the new finds is a collection of alga-like cells sticking to the surface of a one-winged spore (pl. 1, figs. 11, 12). The specimen was referred to M. O. P. Iyengar for opinion, and he agrees that these small rounded cells (individual diameters of 3μ to 6μ) are probably of a blue-green alga resembling *Aphanocapsa litoralis* Hansg. among marine forms, and *Aphanocapsa Grevillei* (Hass) Rabenh. among fresh water forms. My colleague, Rama Nagina Singh shares the same view. A fuller account will appear later.

K. R. Mehta

Behar, Bokaro coalfield.—*Correlation of the coal seams of the Bokaro coalfield with the help of microfossils.* A microcopic study of over 300 samples of coal collected by A. B. Dutt from the Kargali Amlo, Bermo, Top Karo, and Jarangdih seams is in progress. The aim is to correlate with the help of statistical study of the microflora, the seams in the eastern and the western halves of the coalfield.

K. Jacob

Central Provinces, Kamthi stage.—*Fossil plants from the vicinity of Kawadsi, Central Provinces.* A collection by B. N. Sinha from the Kamthi beds near Kawadsi was examined. The plant fossils (*Phyllotheca* sp., *Glossopteris indica*, *G. Browniana*, and a species *Dadoxylon*) are associated with shells of the Phylloped crustacean, *Eastheria munata* var. *Brodieana.* The small number of the plants and this association suggest that the Kawadsi beds may belong to the upper part of the Kamthis.

Hyderabad (Deccan).—*Dadoxylon from the Kothaguedem coalfield of Hyderabad.* A petrified tree trunk from the Barakar sandstone in Kothaguedem coalfield was identified as *Dadoxylon.* The internal preservation was too poor for specific determination. The trunk was discovered by S. Narayanaswami.

K. Jacob

Punjab Salt Range.—*Calcareous algæ from the Salt Range.* A paper describing the calcareous algæ and fusilinids from the middle Productus limestone of the Nammal gorge (30° 40′ : 72° 49′) is ready for the press. The genus *Gymnocodium* (*Palæobotany in India—VI, p. 249*) is recorded for the first time from India. The fusilinids and the algæ show the middle Productus to be of late Permian age.

S. R. N. Rao and C. P. Varma

China, Central Shansi.—*A cordaitean stem from Central Shansi.* A silicified specimen collected by F. L. Yuan from Taiyuan district (37° 8′ : 112° 6′) is considered by us to be another type of Cordaitean stem of the *Gigantopteris*-flora. It is devoid of annual rings, resin canals, and resin cells in the wood. Bordered pits are confined to the radial walls of the tracheids and are uni- to triseriate. The medullary rays are uni- to biseriate, about 1 to 10 cells in height. One to four bordered pits are seen in a cross field.

J. Hsü and M. N. Bose

LOWER GONDWANA

Nepal, Suparitar.—*Microfossils from a lower Gondwana sandstone in Nepal.* A few specimens of sandstone and shaly sandstone, suspected to be of lower Gondwana age, were examined for microfossils. On maceration a few pieces of tracheids with uniseriate, more or less contiguous pitting, and some spores (probably pteridophytic) with a trilete were obtained. The microfossil evidence, so far, is not sufficient for drawing conclusions regarding the age of this sandstone.

K. Jacob

Central Provinces, Damua coalfields.—*A new species of Dadoxylon from Central Provinces.* A well preserved gymnospermous wood from the Damua coalfields shows the following anatomical characters: Growth rings well marked, wood parenchyma absent;

radial pits 1-3 seriate, separate or showing various degrees of contiguity, with pores usually circular and large. Medullary rays triseriate, 1-30 cells hign ; pits in the field 1-9, simple usually round. This species seems to differ from all the species of *Dadoxylon* known to the author; some resemblance, however, is seen with *Dadoxylon resinosum*, but our fossil differs from it in the thickness of tracheids, nature of medullary rays, and the pattern of the pitting, also in the absence of the resin plugs.

J. K. Verma

Central Provinces, Damua coalfields.—*A fossil gymnospermous wood from Central Provinces.* The fcssil wood from Damua coalfield, collected in July 1949, shows the following characters : Growth rings present ; medullary rays mostly uniseriate, rarely biseriate, 2-22 cells high. Pits on the radial walls mostly uni- or biseriate, flattened transversely or hexagonal ; triseriate pits found very rarely ; pore circular and very large. Resin parenchyma present. Pits in the field 1-6, simple as well as bordered. A feature of considerable interest is that the tangential walls of the tracheids are heavily studded with thickened bands and bordered pitting. Structures resembling rims of Sanio are also seen at places in the tangential section. This is the first wood from this locality to show features different from those of *Dadoxylon.* Further studies from bigger specimens of this wood are being made.

N. C. Varma

TRIASSIC

Australia, Narrabeen and Wianamatta series.—*Triassic plants from Australia.* A collection of Triassic plants sent by the Director, Australian National Museum, Sydney, is under investigation. The specimens, which include species of *Pterophyllum* (Wianamatta series) and *Thinnfeldia* (Narrabeen series), are being studied for their cuticular structure.

K. Jacob

Australia, Leigh Creek coalfield.—*Microflora of the Leigh Creek coal-field, Australia.* The study of the microflora of the upper and lower seams of this coalfield in S. Australia is being made. Maceration has yielded numerous spores and cuticles. The samples were kindly sent by the Chief Geologist, Mines Department, Adelaide.

K. Jacob

China, Central Yunnan.—*Rhætic plants from the I-Ping-Lang coalfield, Central Yunnan.* A collection of plant fossils made by me from the I-Ping-Lang coalfield (25° 1′ : 101° 8′) in 1942 has been investigated. The collection contains different types of leaves and fructifications of pteriodophytes and gymnosperms. The lycopodiales are represented by a single species, *Selaginellites yunnanensis* sp. nov., and equisetales by three species, of which *Noecalamites Carrerei* (Zeiller) is quite abundant in one of the beds visited. Of Filicales more than a dozen species have been obtained : The family Marattiaceæ is represented by fertile pinnæ

of *Marattiopsis* cf. *Munsteri* (Goeppert) and *Danaeopsis* sp. *Danœopsis*-like leaves have been frequently found in India and China, but no fertile frond has so far been recorded. In Osmundaceae we have *Todites Princeps* (Presl.) Gothan and *T. Goeppertianus* (Munster) Krasser. The species belonging to Dipteridaceae are *Dictyophyllum Nathorsti* Zeiller, *Clathropteris meniscoides* Brongn., and *Thaumatopteris fuchsi* (Zeiller). Other fern-like leaves obtained are *Cladophlebis haiburnensis* (L. & H.) Brongn., *C.* cf. *denticulata* (Brongn.), *C. shensiensis* Pan, and a few species of *Sphenopteris*.

The Bennettitales are represented by *Pterophyllum* (at least three species), *Anomozamites Schenki* Zeiller, and *Zamites Sahnii* sp. nov., *Ctenopteris Sarrani* Zeiller, ? *Ctenopteris* sp., *Ctenis* sp. ? *Ptilozamites* (at least two species) and ? *Thinnfeldia* sp. are the members of the *Thinnfeldia*-series which has generally been assumed to be a group of gymnosperms dominant in the early Mesozoic period. The *Nissoniales* have two species of *Nilssonia*. *Baiera guilhaumati* and *Baiera* sp. represent the Ginkgoales. Other fossils are *Podozamites* (at least two species), *Taeniopteris*, and some univeined leaves. There are also five types of detached cones.

The age of this flora appears to be Rhaetic. As a whole it shows the same botanical aspect as the fossil flora of Tongking in Indo-China, though some plants recorded here, e.g., *Lycopodites yunnanensis*, *Zamites Sahnii*, *Danaeopsis* sp., and *Ptilozamites* spp. have not so far been found in Tongking. It has a number of species identical with those found in the Rhaetic beds of Shensi, Kiangsi, and Hunan. The collection does not contain even a single species in common with the Indian Mesozoic plants.

J. HSÜ

China, East Hunan—*Some Rhaetic plants from Liling, East Hunan.* The following species are recorded from this locality (27° 7′ : 113° 6′) :—*Ptilozamites chinensis* sp. nov. (pl. 1, fig. 4), *Zamites Sahnii*, *Anthrophyopsis Leeiana*, *A. Szei* sp. nov. and some species of *Pterophylium*, *Baiera*, and *Podozamites*. All of them are well preserved and have yielded good cuticles. Our specimens of *Ptilozamites* differ from *P. tenuis*, described by Oishi from the Rhaetic beds of Nariwa, Japan, because the former have their pinnæ 2-(rarely 4-) veined. Probably both south China and Tongking had a *Ctenopteris*—*Ptilozamites* flora flourishing during the Rhaetic period. *Ptilozamites* is found for the first time in China.

J. HSÜ

JURASSIC

Behar, Rajmahal hills—**The Pentoxyleae : a new group of Jurassic gymnosperms from the Rajmahal hills of India.* BY B. SAHNI. *Bot. Gaz.* **110** *(1) : 47-80. With 12 plates and 46 text-figs., including 2 reconstructions.* The full paper on Pentoxyleae is now published. This new group was

* Invitation paper presented at the symposium on "Evolution and classification of gymnosperms" conducted at a joint session of the Palaeobotanical section of the Botanical Society of America and the Society for the Study of Evolution, at Chicago, Illinois, December 30, 1947.

first proposed by Sahni during an informal discussion held under the auspices of the Empire Scientific conference of the Royal Society at the Botany School, Cambridge on 25th June 1946 (*Palaeobotany in India—VI, pp. 250-251*).

The foliage leaves known as *Taeniopteris spatulata* are given a new generic and specific name, *Nipaniophyllum Raoi*, with the following characters : " *Petrified leaves having the form and venation of Taeniopteris Brongniart, combined with vascular bundles of the " diploxylic " type characteristic of the modern cycads and stomata fundamentally of the Bennettitalian type with the subsidiary cells liable to subsequent transverse division* ".

Figs. 45 and 46 of the paper give a reconstruction of *Pentoxylon Sahnii* Srivastava, showing the stem, leaves and female cones. This is so far the best known and the commonest of the Pentoxyleae. It is pictured as a branched shrub, possibly a small tree, of xerophytic habit. It had a stem named by Srivastava as *Pentoxylon Sahnii*, and it bore foliage leaves of the type *Nipaniphyllum Raoi*. The flowers are presumed to have been unisexual. They were borne at the ends of lateral dwarf shoots which in appearance resembled the stem of a miniature cycad. The plant had female cones known as *Carnoconites compactum*. The male flowers have not been found, but they may have become shrivelled up by the time the female cones were as far advanced as they are in the fossil material. The present evidence indicates that the Pentoxyleae occupy a unique and rather isolated position, despite certain affinities with both the *stachyosperm* (with seeds borne on stems) and the *phyllosperm* (with seeds borne on leaves) divisions of the gymnosperms.

R. V. SITHOLEY

Behar, Rajmahal hills—**Nipanioruha granthia gen. et sp. nov., a new petrified coniferous shoot from the Rajmahal hills, Behar. Jour. Ind. Bot. Soc. Iyengar Commem. Vol: 389-397. 1946. (Issued 1947). With 6 plates and 1 text-fig.* A new type of petrified coniferous shoot is described from the Jurassic of Nipania. The wood is pycnoxylic with uniseriate bordered pits. The leaves are needle-like and spirally placed ; they have a single central vascular bundle underlain by a secretory canal and surrounded on all sides by palisade tissue. The typically coniferous stomata occur only on the upper surface of the leaf. The affinities of the new genus are obscure but a comparison is suggested with some Podocarpineaen and Cupressinean shoots.

A. R. RAO

Behar, Rajmahal hills—**On a collection of Jurassic plants from the Rajmahal hills, Behar. Ibid: 51-95. 1946. (Issued 1947). With 7 plates and 13 text-figs.* The paper gives an account of a large collection from four localities, namely, Onthea, Lalmatia, Maharajpur and Khairbani. Of the 45 different species in the collection 8 are new, including 3 new genera (*Palaeobotany in India—VI*, p. 250). This work confirms the view held by most of the previous workers that the Rajmahal series is of Jurassic age, and probably younger than the Lias.

P. N. GANJU

Behar, Rajmahal hills—*On a cluster of male cones from the Rajmahal hills.* A cluster of five oval cones (size 5-7 mm. × 20-22 mm.) similar to *Strobilites Pascoei* and *S. ontheaensis* has been found in Onthea. The sporophyll has a narrow base and an expanded upturned apex, and it possesses on elongated sporangium. The spores obtained are cf an elongated hexagonal shape, very much like those found in a strobilus (also from Onthea) doubtfully assigned by Sahni to *Elatocladus conferta.*

D. D. PANT

Burmah, Shan States—*Fossil plants from the Shan States.* The material was collected by V. P. Sondhi of the Geological Survey of India from the coal-measures of the southern Shan States. Petrological examination of the matrix of the specimens by R. C. Misra showed that they are metamorphosed ; it is thus not surprising that the specimens, while superficially appearing rich in fossils, have yielded only a few well preserved impressions. On maceration also, they have yielded only a number of fragmentary, structureless carbonised pieces. The genus *Scleropteris* is reported for the first time from Burma ; it is represented by only one species, *S. furcata* Halle. *Sphenopteris rotundiloba* Sap. is also being reported for the first time from this area. Besides these two well preserved forms, three imperfectly preserved species of *Sphenopteris*, three species of *Zamites*, and a few other unidentifiable plant remains have been recorded. The palaeobotanical evidence, though meagre, tends to support a mid-Jurassic age for the coal-measures as proposed in 1922 by Cotter, who described six well defined plant genera from the Loi-an coalfield.

B. S. TRIVEDI

Afghanistan, Saighan series—*Fossil plants from the Saighan series of Afghanistan.* A collection made by W. D. West and F. Ahmad chiefly from the Ishpushta valley, Marak, and Darra Tor during the investigations of the Government of India's coal survey party (1940-42) is being worked out. The following is the provisional list of the species recognised.

EQUISETALES : *Equisetites ferghanensis*, *E.* cf. *naktogensis.*

FILICALES : *Todites Williamsoni* (fertile frond), *Cladophlebis haiburnesus*, *C. denticulata*, *C. triangularis*, *C.* cf. *exisiformis*, *Cladophlebis* sp., *Klukia exilis* (fertile frond), *Coniopteris quinqueloba*, *C. arguta*, *C. hymenophylloides* (fertile frond), *Sphenopteris* (*Coniopteris*) *hymenophylloides*, *Sphenopteris* spp. *Haydenia thyropteriodes*, *Eboracia lobifolia*, *Dictyophyllum* (? *Clathropteris*) sp., *Laccopteris* cf. *polypodiodes.*

CYCADOPHYTA : *Pterophyllum* (? sp. nov.), *Ctenis fallax*, *Ctenis* cf. *falcata*, *Nilssonia* sp. *A.*, *Nilssonia* sp. B.

GINKGOALES : *Ginkgoites* sp., *Stenorachis lepida.*

CONIFERALES : *Pagiophyllum* (*Elatides*) *curvifolium*, *Elatocladus* (? *Taxites*) sp., *Pityophyllum* (? *Pinites*) sp., *Conites* sp.

CAYTONIALES : *Sagenopteris Phillipsi.*

INCERTAE : Slender fertile cones (? *Equisetales*).

Ctenis fallax and *Pterophyllum* (? sp. nov.) yielded excellent cuticles. Sporangia with apical annulus, characteristic of the Schizaeaceae, were observed in certain fertile fronds of *Klukia exilis*. The sporangia yielded numerous spores on maceration. The flora considered as a whole indicates a Jurassic age. Whether the beds are to be referred to the lower, middle or upper Jurassic is at present difficult to judge with certainty. The present collection lends support to the view already expressed by H. H. Hayden that the Saighan series belongs to the Angara rather than the Gondwana province. The study of the microflora of the Saighan series is also in progress.

K. Jacob

South India, Trichinopoly district—**On two species of Solenopora from the Cullugoody limestone of the Trichinopoly district, S. India. Journ. Ind. Bot. Soc. Iyengar Comm. Vol.: 331-337. 1946.* (*Issued 1947*). *With 1 plate and 2 text-figs.* Two species, *Solenopora jurassica* Nich. and *S. coromandelensis* sp. nov. are described and figured (*Palaeobotany in India IV, p. 178 ; figs. 11-12*). *S. coromandelensis* is very common at Cullygoody. It combines characters of the normal type of *Solenopora* with those of *Parachaetetes* and *Pseudochaetetes*. On the evidence of *S. jurassica* the age of the cullygoody limestone appears to be lower to middle Oolite.

S. R. Narayan Rao

Ceylon—*The Upper Gondwana flora of Ceylon.* This short note reviews the plant fossils of upper Gondwana affinities so far recorded from Ceylon. In all there are seventeen species of described from Tabbowa beds, a group of shallow water non-marine deposits of Jurassic age, which most probably belong to the upper Gondwana facies. As more and more material is coming forward the conclusions reached by Seward and Holttum 26 years ago about the close affinities between the Jurassic flora of Tabbowa and that of the Madras coast of South India are being amply justified.

R. V. Sitholey

China, Sinkiang—*Xenoxylon phyllocladoides Gothan from Sinkiang.* The material consisting of a large number of woods was collected by F. L. Yuan from the Tihua district (43° 8′ : 87° 8′). All the specimens are identical with *Xenoxylon phyllocladoides* described by Gothan from the Jurassic of Europe. Woods of this type have already been recorded from some Jurassic beds in Manchuria and Jehol. The occurrence of this species in the Tihua beds suggests that conifers with this type of wood were dominant in the northern half of China during the Jurassic period. It also suggests a Jurassic age for the Tihua beds.

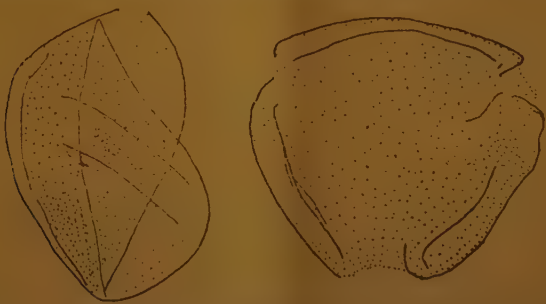
J. Hsü

China, South Hunan—*Two coniferous woods, Xenoxylon and Cupressinoxylon from south Hunan.* The specimens occur in the form of two big petrified logs and were collected by the Hunan Geological Survey from Ningning (26° 3′ : 111° 6′). They have been identified as *Xenoxylon latiporosum Gothan* and *Cupressinoxylon fujeni* Mathews and Ho. The first species was described from the Jurassic of Europe and is also recorded in Manchuria. *C. fujeni* has been found in the Jurassic beds of Chahar (inner Mongolia). The presence of these woods indicates a Jurassic age for the Ningning beds.

J. Hsü

? JURASSIC OR TERTIARY

Rajasthan, Barmer—*Angiospermic remains from the Barmer sandstones and associated clays in Rajasthan.* The material was collected by S. K. Barooah, Director, Department of Mines and Geology, Jodhpur, and myself from a dry well near the foot of the hills which are situated about a mile north west of the Barmer town (25° 40′ : 71° 25′). The dark carbonaceous clay when split yielded a number of impressions of dicotyledonous leaves and a few stem impressions and incrustations.



Text-Fig. 1. Pollen from a carbonaceous clay near Barmer. (x 1020).

Small pieces of the leaf bearing matrix, macerated with Schulze's mixture ($HNO_3 + KClO_3$), have revealed a large number of angiospermic pollen grains along with a few which appear to be of gymnospermous nature (text-fig. 1). There are also present some spores of the tetrahedral type and a good number of fungal spores of several varieties from unicellular to multicellular (pl. 1, fig. 7). Many of the pollen grains have clearly preserved germ pores. The fossil leaf shown in pl. 1, fig. 5 was collected from Lunu, 5 miles from Barmer. The Lunu beds belong to the Barmer Sandstone horizon.

There are two views regarding the age of the Barmer Sandstone. W. T. Blanford (1876 *Rec. Geol. Surv. Ind.* **10**) correlated them with the marine Jurassic beds of Jaisalmer. T. D. La Touche (*1902, Mem. Geol. Surv. Ind.* **35** (I)) thought that as the Barmer sandstones contained dicotyledonous remains they could not be older than the Cretaceous.

M. S. Krishnan in his " Geology of India and Burma " (1943, pp. 252 and 374) says that these may be of the same age as the Himmatnagar and Umia sandstone. The present discovery of definitely angiospermic leaves from the Barmer rocks is of considerable interest because, as far as I know, there is no published description or figures of the dicotyledonous remains mentioned by La Touche. Discussion of the age of the Barmer strata in the light of the fossils now found is reserved till the material has been worked out in detail.

M. N. Bose

JURASSIC AND CRETACEOUS

Punjab, Salt Range—*Mesozoic gymnosperms from the Salt Range, Punjab.* The remaining part of the collection made by E. R. Gee and N. K. N. Aiyengar from this area has now been described. The part dealing with the ferns has already been published (*Proc. Nat. Acad. Sci. Ind.* **15** (*3*)*: 61-76. 1946*). The Bennettitales and the conifers are dealt with in the description now completed. Of the three new species of *Otozamites* in the collection one, namely *O. pecten* has already been mentioned in " Palaeobotany in India "—IV, p. 178. The other two have been named *O. oblongus* and *O. sakesanensis*. *O. oblongus* has rather distant pinnae, oblong with parallel sides and a broadly rounded apex. In *O. sakesanensis* the pinnae are linear, sometimes falcate, with the apex rounded and turned backwards. Consistent with the external differences of shape and size, the cuticular structure of the species is also distinctive. The collection is of Jurassic age with the exception of a number of specimens of *Ptilophyllum* which are probably younger (Cretaceous).

B. Sahni and R. V. Sitholey

CRETACEOUS

South India, Trichinopoly district—*Fossil algae from the Niniyur group of the Trichinopoly Cretaceous.* In the memoir published in 1936 (*Pal. Ind. N.S.* **21** (4)), an account was given by J. Pia and myself of the Dasycladaceæ occurring in this group. It was seen that practically all these were contained in the cherts associated with the group and particularly well seen near the village of Nattagooly. A further collection of similar cherts from other parts of the area has since been made, and sections of these reveal an extraordinary abundance of Dasycladaceæ. In fact, in some cases the entire specimen is almost one mass of these algal remains. A preliminary study of these sections shows the common occurrence of the two forms, *Dissocladella Savitriae* and *Indopolia Satyavanti*, already described; but in addition to these, several more types are recognisable which appear to be new. The entire material is exceedingly well preserved, and a detailed study is under progress.

L. Rama Rao

China, east Shantung—*Brachyoxylon Sahnii, a new species of coniferous wood from Shantung.* The fossil wood was collected from Ma-an-shan of the Chi-me district (36° 4′ × 102° 5′), East Shantung.

It is composed of only tracheids and medullary rays. Annual rings and resin canals are lacking. Bordered pits are found on the radial walls of the tracheids. They are uni-to biseriate, separate, rounded, and large, but sometimes becoming slightly flattened by mutual contact. Biseriate pits are confined to the part of tracheids adjacent to the rays. Tangential pits are rare, smaller, and separate. Medullary rays are uniseriate, rarely biseriate and then only in parts ; they have simple pits which are confined to the radial walls. The pits in the field number about eleven. Some branched septate hyphæ with clamp connections are seen inside the ray cells. They appear similar to those of the recent wood rotting Polyporaceæ.

Wood of this type has so far been recorded from the Cretaceous beds of Staten Islands (New York) and Urkawa series of Japan. The specimens from Staten Islands have been described by Hollick and Jeffrey as *Brachyoxylon notabilis.* The woods from Japan have been named by Shimakura as *B.*aff. *Woodworthianus* and *Brachyoxylon* sp. The Chinese species differs from *B.notabilis* is having a less number of pits in the field ; it differs from *B.Woodworthianus* and *B.*sp. in not possessing bi-to triseriate pitting on the radial wall cf the tracheids. It is therefore provisionally named as a new species, *Brachyoxylon Sahnii.*

J. Hsü

CRETACEOUS—EOCENE

Waziristan—*Algal remains from Waziristan.* A study of the algal remains collected by H. Crookshank near Razmak camp, Waziristan, from rocks " variously stated to be Mesozoic to Eocene ", revealed that some of the impression were identical with those previously described by me from the Janjal plant series, Takki Zam valley, Waziristan (*Journ. Ind. Bot. Soc.* **17** *: 173-176*). *Algites* cf. *A, intricatus*, A. cf. *A.targioni*, *Algites* sp. 1 and *Algites* sp. 2 were provisionally determined. The algal remains from Razmak are believed to be of about the same age as those of the Janjal plant series.

K. Jacob

TERTIARY

Punjab, Salt Range—**Microfossils and the Salt Range thrust. Opening address at the second symposium on the age of the saline series, held at Udaipur on 27 and 28 December 1945, under the joint auspices of the National Academy and Indian Academy of Sciences. By B. SAHNI. Proc. Nat. Acad. Sci. Ind.* **16** *(2-4) : i-1.1946.* (*Issued 1947*). *With 11 plates and 36 text figs.* The address commences with an outline of the results achieved by the first symposium at Poona. In accordance with the suggestions for further work made during that symposium one more excursion to the Salt Range was organised in October 1945. In this excursion Sahni and J. Coates were conducted by E. R. Gee on a fortnight's traverse of nearly the entire length of the Salt Range, from Kalabagh on the Indus in the west to Jalalpur on the Jhelum near the eastern extremity of the mountains. A detailed account is given of the areas visited and of the data gathered from the study of sections and microfossil analysis of the samples collected in the course of the four. The

places visited include Kalabagh, Daud Khel, Chittidil, Warchha and Chhabil, Fatehpur Maira, Khewra, Kallar Kahar, and Jalalpur. From the evidence gathered as a result of work in the laboratory and in the field two main facts emerge : (*i*) that most of the sedimentary rocks of the saline series are rich in microfossils, and (*ii*) that the flora and the fauna (mainly woods of gymnosperms and angiosperms, plant cuticles, and insect remains) show an essential similarity throughout. Although these fossils are not datable within narrow limits, the angiosperms are at least as young as the Jurassic and some of the insects must be Tertiary. The gymnosperms go back to the Devonian but even that period is far younger than the Cambrian.

The Geologists of the Cambrian school have endeavoured to explain the occurrence of microfossils in the saline series by their theory of contamination. The possibility of plastic sediments like rock salt and kallar having been contaminated locally through cracks or solution holes is not wholly denied ; at the same time it is difficult to accept that such contaminations have taken place on a microscopic scale over a wide area and in such a refined manner as to have injected all the strata in Khewra and Warchha mines (from which our samples were taken) with micro remains of the same general types, without at the same time permitting the intrusion of the associated organic matter. Moreover the later samples to be analysed were all either oil shales or dolomites, which, by their very nature, would hardly be suceptible to the process of contamination envisaged by these geologists. Arguments are also advanced against Lehner's theory of " structural intermixing " and " assimilation " of foreign rocks in the saline series and Pinfold's objections, according to which the microfragments belonging to recent plants and animals were accidentally introduced into the rock. It was suggested at Poona that as a check against the contamination theory some test samples of rocks of known geological ages be examined. These tests have been carried out and have uniformly given consistent results. No puzzling anomalies have come to light which would serve to cast doubt on the testimony of the microfossil evidence.

In the interpretation of stratigraphical contacts where fossil control is not readily available imagination and personal factor may play a large part. There are parallel cases in the other parts of the world where great overthrusts, of which the existence was long disputed because the stratification appeared to be undisturbed, have been demonstrated by eminent geologists and are now universally accepted. Where field evidence appears to conflict with the evidence of fossils we must be prepared to agree that there may be something wrong with our reading of the field evidence.

R. V. SITHOLEY

Punjab, Salt Range—**The age of the saline series : a review. Second symposium on the age of the saline series, Udaipur. Proc. Nat. Acad. Sci. Ind.* 16 *(2-4) : 255-257. 1946.* (*Issued 1947*). The author was previously inclined to doubt the *in situ* nature of the microfossils obtained from the salt and the marl beds. Later work has shown that the same types of microfossils are also found in the associated dolomites

and oil shales. The possibility of looking upon these organic remains as adventitious in character due to their intermittent infiltration into strata, characterised by softness, solubility, and plasticity can hold good in the case of the salt beds only. It is difficult to extend this explanation to the fossils in the dolomites, and much more so to those found in the oil shales. Oil shales of different ages have been studied in several parts of the world and it has always been assumed—there is no reason to think otherwise—that the contained organic remains in each case belong to the contemporary faunas and floras. There is no doubt—all the field geologist including E. R. Gee agree—that the oil shales are an integral part of the stratigraphical succession constituting the saline series. This makes the palæontological evidence put forward by Sahni convincing and decisive.

L. RAMA RAO

Punjab, Salt Range—*Tertiary microfossils from the cherts of the saline series.* Interbedded with the dolomites and the kerogen shales of the saline series are cherty beds. Thin sections of the cherts from these beds have been examined for microfossils and have led to a discovery in them of great interest, namely, the spicules of the calcarecus alga *Acicúlara* (pl. 1, fig. 10). The earliest record of this genus is from the Cretaceous, but the long and needle shaped spicules found here are comparable to the Tertiary forms ; they thus indicate the same age for the cherts ; the Tertiary age is also supported by the foraminifers found in them. The present work confirms the opinion held by Sahni that the saline series are Eocene and not Cambrian or pre-Cambrian in age.

S. R. N. RAO and C. P. VARMA

Punjab, Salt Range—*Microfossils from an oil shale of the saline series in the Fatehpur Maira gorge.* Maceration of further samples of the oil shale has revealed besides shreds of woods similar to those previously found by Sahni (*1947, Proc. Nat. Acad. Sci. Ind.* **16** *(2-4): ix-xiii*) a number of spores and pollen grains. Some of the spores have a tri-radiate mark and the pollen grains show definite germ pores.

PRATAP SINGH

Central Provinces, Wardha district—**Palmoxylon sclerodermum Sahni from the Eocene beds of Nawargaon, Wardha District., C. P. Jour. Ind. Bot. Soc.* **25** *(3): 105-116.* 1946, *With 4 plates and 8 text-figs.* On the basis of a more complete specimen than the type specimen the species *P. sclerodermum* Sahni is redescribed. In addition to the investigaticns made by Sahni, the anatomy of the leaf base region (the cortex), the central region and also the roots of this species has been studied. It has thus been possible to establish a more complete diagnosis of the species. A comparison of the present specimen with others described by Stenzel confirms the fact, which he admits, that the basis of his classification is artificial.

V. B. SHUKLA

Central Provinces, Mohgaon Kalan (Chhindwara district)—*Sahnipushpam gen. nov. and other plant remains from the Deccan intertrappeans.* Some more specimens of the flower with pentalocular ovary mentioned in "Palæobotany in India"—VI, p. 259 (pl. 18, figs. 12, 13) have been discovered and have revealed further anatomical details. The flower is now named *Sahnipushpam gen. nov.*

Spirogyrites gen. nov. Lying in close association with some pieces of stem and roots of aquatic plants there have been found several filaments very closely resembling *Spirogyra.* The filaments show at places transverse walls and in some of the cells are present spiral chloroplasts. The edges of the chloroplasts are not smooth and the number of coils is two. Other slices of cherts which are yet in the process of final polishing show some more algal material. The name *Spirogyrites* is proposed for these filaments.

A new specimen of Tricoccites. A fruit-bearing axis with nearly twenty fruits has recently been discovered. As seen in the horizontal fracture, the triangular fruits are arranged along two rows. The new specimen has revealed further details of the fruit structure. A restoration of the entire fruit-bearing axis is being attempted.

A new fruit-bearing axis with six locular fruits (pl. 2, figs. 13, 14). An interesting fruit-bearing axis measuring nearly 7 cm. in length and 1·5 cm. in width was discovered in a block of chert. Due to the greatly oblique position of the axis in the matrix, the photographs show the fruits in its basal portion cut transversely and those in the upper region cut longitudinally. The fruits are six-locular. The internal structure is preserved in some cases. The specimen has been found in association with *Cyclanthodendron* stems. The details of the anatomy are being worked out.

A fossil dicotyledonous leaf (? *Lythraceae*). The leaf impression seen in pl. 2, fig. 16, was found in close association with some *Enigmocarpon* seeds. The shape and outline of the lamina, the apex, the form of the midrib, the curvature of the veinlets, especially near the tip, and the angle of the secondary veins, all very closely recall a leaf such as that of *Lagerstroemia indica.* Traces of the inframarginal vein are also seen in the left half of the specimen. The occurrence of such a leaf in beds containing plant fossils of lythraceous affinities, such as *Enigmocarpon* and *Sahnianthus* is significant.

Central Provinces, Bharatwada hills—*A new Enigmocarpon locality.* From the Bharatwada hills near Nagpur several fruits of *Enigmocarpon*, including a pretty and well preserved specimen, have been discovered. Bharatwada is 120 miles distant from Mohgaon Kalan. The topographical and geological nature of the two localities is very similar.

Central Provinces, Sagar district—*A multilocular fruit from the Tertiary of Sagar.* Some years ago several specimens of a multilocular fruit embedded in sandstone were discovered from Tertiary beds of Sagar. While it has not yet been possible to ascertain the exact affinities of this specimen, in external form it resembles the fruit of Malvaceæ.

V. B. SHUKLA

Central Provinces, Mohgaon Kalan (Chhindwara district)—*A fossil dicot wood from the intertrappean cherts of Mohgaon Kalan.* A well preserved wood (pl. 2, figs. 17-19) showing the pith, primary xylem, secondary wood, and bark has been collected. The specimen is 16 mm. in diameter and occurs in association with *Enigmocarpon* and *Sahnianthus*. It shows the following characters : Primary xylem elements with spiral thickenings. Considerable portion of the pith present, abutting against the protoxylem. Growth rings absent. Pores numerous, small, barely visible to the naked eye, quite uniform in size, and evenly distributed. Pore chains and pore clusters common ; contiguous rays on one and generally on both sides of the pore. Perforations simple, nearly horizontal to oblique. Inter-vessel pits numerous, widely spaced, circular or oval with wide border. Tyloses sparse, cyst like. Longitudinal parenchyma wanting. Fibres thin walled, angled in the transverse section, definitely aligned in radial rows. Rays not visible with the naked eye, of two types : (1) uniseriate, fine, regular, and very close, separated by 1-6 fibres, homogeneous ; and (2) aggregate rays which are few, heterogeneous, with 1-3 resin canals in the body of the ray. The fossil shows resemblance with the wood of *Sonneratia* belonging to the *Lythraceae.* The chief points of resemblance are : vessels borne in radial rows and evenly distributed, perforations simple, tyloses present, longitudinal parenchyma wanting, fibres more or less angled in the transverse section and arranged in radial rows ; the fine rays which are regular and frequently very close. The occurrence of this wood in association with *Enigmocarpon* and *Sahnianthus* is suggestive. Mrs. S. D. Chitaley has recently discovered a chert from the same locality with numerous well preserved *Enigmocarpon* fruits in close association with a number of dicot twigs of varying diameters. The anatomy of one of these woods is very much similar to the wood described above.

J. K. VERMA

Central Provinces—*Microflora of the Deccan intertrappean cherts.* Three types, including two types of spores, have been discovered.

N. C. VARMA

Central Provinces, Mohgaon Kalan (Chhindwara district)—*Microflora of the Deccan intertrappean cherts. Maceration* of some promising chert material has yielded several interesting types of spores and pollen, and septate hyphae with spores akin to those of the Mucorales. The four celled fungal spore (pl. 2, fig. 21) is common ; it resembles Hirmer's type *Chaetosphaerites.* The sculpturing on the walls of some of the pollen grains recalls that of the pollen of the genus *Barnadesia* of the Compositae. Some of the pollen and spores (*e.g.*, that in pl. 2, fig. 20) bear resemblance to those found in the Assam Tertiary beds.

(MRS.) S. D. CHITALEY

Central Provinces, Mohgaon Kalan (Chhindwara district)—*The leaf of Cyclanthodendron Sahnii (see Palaeobotany in India—V, pp. 83-84 and VI, p. 258 ; Nature,* 154 *(3899) : 114-115).* A petrified leaf was

discovered in a fresh collection made by one of the authors from Mohgaon Kalan recently. The specimen (p.1, fig. 9) represents a part, most probably the lower portion, of the leaf. The surface of the leaf shows prominent ridges and furrows. In external appearance it resembles the leaves of some species of the living genus *Carludovica* (*Cyclanthaceae*). It was therefore suspected that the fossil leaf belonged to *Cyclanthodendron Sahnii*. The suspicion was confirmed when a transverse section was prepared from the lower end of the specimen. The internal anatomy is exactly similar to that of the leaf-sheaths which surround the stem of this species. Under the upper epidermis is present a layer of elongated palisade cells, while the rest of the tissue is made up of round cells. Two vascular bundles, one below the other, are situated in the ridges, while there is only one present in the furrows. A vascular bundle possesses two well developed sclerenchymatous sheaths, dorsal and ventral, and the xylem vessels are arranged one below the other in a row. Air canals are also present.

The external form as well as internal anatomy leaves no doubt about this fossil leaf belonging to *Cyclanthodendron Sahnii*. We are thus in possession of complete plant of this fossil member of the Cyclanthaceae, except for the petiole and reproductive organs. They, we feel, need only intensive searching at the fossil locality.

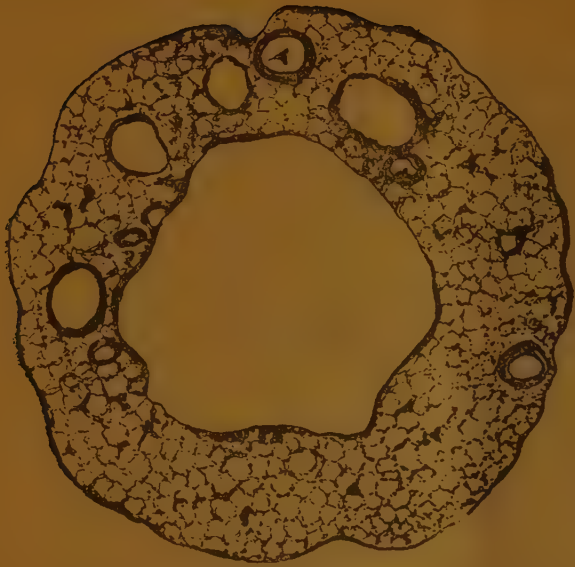
B. SAHNI and K. R. SURANGE

Central Provinces, Mohgaon Kalan (Chhindwara district)—*Some new fossil plants from the Deccan Intertrappeans*. The following material was collected during 1945-46 from different localities in the neighbourhood of Mohgaon Kalan at the suggestion of B. Sahni, who also was good enough to examine the specimens and confirm that they were new.

(1) *Palmocarpon insigne* sp. nov. (pl. 1, fig. 8). This is a small round fruit resembling the fruits of modern palms like *Bactris*, *Howea*, *Pritchardia*, etc. It is 1·4 cm. in diameter and a typical drupe. The epicarp is thin ; below it are crowded a large number of fibres and bundles. Some of the fibres are stellete and run obliquely and lie on the hard endocarp. Lying flush with the endocarp, there is a uniform layer of chalcedony which probably represents the albumen. The fruit probably belongs to some *Ceroxylinae*.

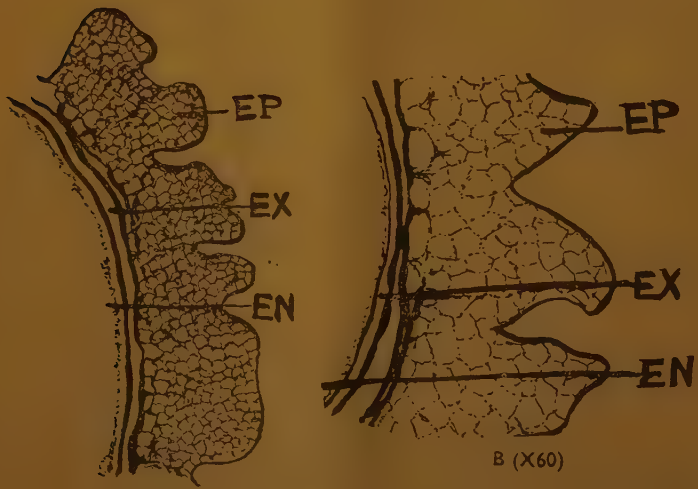
(2) *A mould of palm inflorescence*. On a small piece of reddish chert there are impressions having the appearances of a female palm inflorescence after the fruits have fallen off. The inflorescence was perhaps a compound one, as suggested by the occurrence of several other similar impressions on the same small piece of chert. The fossil suggests comparison with the inflorescence of genera like *Bactris*, and the female inflorescence of *Hyphaene* but its real affinities are not known. The name *Palmostrobus* has been proposed for it.

(3) *A floral axis of Palm*—Two pieces of stem, looking externally very much like the floral axis of some modern palm, were collected. One of them was ensheathed by bracts and the other also had



Text-fig. 2. (X250)

Text-fig. 3. (X60)



A (X250)

B (X60)

Text-fig. 4.

Text-fig. 2. Hollow massula of *Salvinia auriculata* Aubl. (× 250).

Text-fig. 3. Megaspore of *Salvinia auriculata*. (× 60). *EP, episporium ; EN, endosporium ; EX, exosporium.*

Text-fig. 4. A. The three spore coates of the megaspore of *Salvinia auriculata* to show the episporial frill. (× 250). *EP, episporium ; EN, endosporium ; EX, exosporium.*

B. The three spore coates of *Sausarospermum* to show the spongy episporial frill, EP; hard and uniform exosporial coat, EX; and layer of endospore, EN. (× 60).

impressions of leaves on it. Their anatomical characters, however, reveal that they probably belonged to the *Cyclanthaceae*, perhaps to *Cyclanthodendron Sahnii.* This was evident from the occurrence in them of typical, large fused compound bundles, so characteristic of the Cyclanthaceae ; but the arrangement of the vascular bundles, sclerenchyma strands and the other cortical tissues is different from that in the stem of *Cyclanthodendron.* A comparison of the fossils with the floral axis of Cyclanthaceae such as *Carludovica palmata* shows that there is a strong resemblance between the structures of the two. It is, therefore, probable that these two pieces represent the floral axis of a fossil palm perhaps *Cyclanthodendron* which was also discovered at Mohgaon Kalan.

(4) *The genera Massulites and Sausarospermum.*—From a detailed study of the development of the sporocarps in the three species of *Salvinia*, *S. cucullata Roxb.*, *S. auriculata Aubl.*, and *S. natans Hoffm.*, it is found that the massula is hollow in *Salvinia auriculata* at a certain stage of its development and continues to be so for a long time (text-fig. 2). This shows that the genus *Massulites* of Sahni and Rao represents this hollow massula of some fossil species of *Salvinia*, allied to the modern species, *S. auriculata.* There is also a strong resemblance between the morphology of the puzzling genus, *Sausarospermum*, discovered in these cherts by Sahni, and the megaspores of *Salvinia auriculata* and some other species (see text-figs. 3, 4). There thus seems ample indication of the occurrence of the genus *Salvinia* in the Deccan intertrappean series. If this is so it would provide additional support to the Tertiary age assigned to them by Sahni, as all the previously known records of *Salvinia* are either from the Tertiary or the post-Tertiary periods. But whether the fossil species in the Deccan intertrappeans is identical with any of the living species is a moot point. Most probably it is not.

T. S. MAHABALE

Bombay Presidency, Worli hill—*Microfossils from Worli hill intertrappeans, Bombay.* Bits of matrix collected by R. N. Sukheswala from the Worli hill intertrappeans were analysed for microfossils. The pieces of matrix were associated with the fossil fresh water tortoise, *Hydraspis leithii.* They have yielded several microspores, both with and without wings.

K. JACOB

Assam, Nailalung—*On the anatomy of Cynometroxylon indicum gen. et sp. nov., a fossil dicotyledonous wood from Nailalung, Assam—Proc. Nat. Inst. Sci. Ind.* 12 *(8): 435-447, 1946. With 2 plates.* This fossil wood was collected along with several others near Nailalung railway station, 14 miles east of Lumding junction on the old Bengal Assam Railway. The age of the fossil appears to be Upper Miocene. A detailed study of the specimen has been made and it has shown affinities to the living genus *Cynometra* of the Leguminosae. Comparison of this fossil with those previously identified from India and outside has been made

and their possible affinities discussed. The fossil appears to be the first wood specimen allied to *Cynometra*, so far recorded, and is named *Cynometroxylon indicum*.

K. A. Chowdhury and S. S. Ghosh

Assam, Thailangathu nadi bed—*Kayeoxylon assamicum gen. et sp. nov., a fossil dicotyledonous wood from Assam.* This fossil wood specimen was collected from the bed of Thailangathu river near the 8th milestone on the Dhansiri Manglumukh cart road (93° 43′ : 26° 32′). Geologically the locality is known to be upper Miocene. A detailed anatomical study has shown its affinities to the living genus *Kayea* of the *Guttiferæ*. It is therefore named *Kayeoxylon assamicum*.

K. A. Chowdhury and K. N. Tandon

Assam, Nowgong district—*Fossil wood* (*Glutoxylon*) *from Assam.* Examination of about 20 small pieces of fossil wood from this area shows that they all belong to *Glutoxylon*. An intensive study of these specimens, along with those from Nailalung formerly identified in this laboratory, is being made. It is interesting to note in this connection that some fossil wood specimens reported from Burma and Indo-China show a great similarity with the specimens under investigation. It is quite likely that the specimens from Burma and Indo-China will have to be re-examined and probably re-identified.

K. A. Chowdhury

Rajasthan, Kapuria beds—*Fossil plants from Kapuria, Jodhpur.* The Kapuria beds (25° 54′ 30″ : 70° 22′ 30″), 13 miles from Barmer in Jodhpur State, are formed of Fuller's earth and cover an area of about one and half square miles. They are probably of Laki age. The author collected from here in April 1948, in company of S. K. Barooah, impression of dicotyledonous and monocotyledonous leaves, fruits, and stems. The plant fossil are associated with impressions of echinoids, fishes and arthropods. The majority of the dicotyledonous leaves belong to a species, showing resemblance with *Mesua ferrea* (Guttiferæ). A detailed investigation of these specimens is in progress.

M. N. Bose

Madras Presidency, Cuddalore—*Microfossils from lignite deposits in Cuddalore.* Numerous types of angiospermic pollen and pteridophytic spores were recovered from core samples of Tertiary (? Miocene) lignite deposits of Cuddalore in South Arcot. The samples were collected by R. N. P. Arogyaswamy and G. V. D. Upadhyaya.

K. Jacob

Burma, Shan States—*Tertiary fossils from the Shan States.* An investigation of Tertiary fossils from the following localities is in progress : (*a*) Lacustrine deposits, 2 miles south of Kengtung. (*b*) Lignite beds, 1 mile south-west of Kengtung. The exact horizons are not known. They

are reported to be of late Tertiary, Pliocene or Pleistocene age. The first locality has yielded impressions of dicotyledonous leaves which, with two exceptions, are rather fragmentary. The lignite bed contains a very rich microflora, comprising of several kinds of pollen grains, spores, and cuticles.

J. P. SRIVASTAVA

Assam[1]—*Correlation of the Tertiary Succession in Assam by means of microfossils.* In " Palaeobotany in India "—VI it was recorded that research at Lucknow University, undertaken on behalf of the Burmah Oil Company, had shown that many of the Assam Tertiary rocks were rich in plant microfossils, which showed considerable variety and which appeared to contain certain types characteristic of the main stratigraphic series.

The Burmah Oil Co. (I. C.) Ltd., have since been continuing the palaeobotanical work, mainly with the objectives of (a) extending and confirming the results with a larger range of samples, (b) seeing whether means can be devised for dealing more rapidly with the samples examined, as the examination in the fundamental stages of the research has been of necessity rather slow, and (c) devising a system of classification and graphic representation so that the results can be readily appreciated and conclusions can be speedily reached.

Some progress has been made in all three of these directions, but the speed with which the investigations can be carried out is still so slow that it may be some time before the results of examination of plant microfossils can be used for geological correlation of the rock succession exposed in different parts of Assam.

PLEISTOCENE

Kashmir, Karewa beds—**Some fossil leaves and fruits of the Aceraceæ from the Karewa deposits of Kashmir, with remarks on the past and present maple forests of Kashmir valley. Proc. Nat. Acad. Sci.*, **22** *(5) B: 279-298, 1945. With 6 plates.* Ten species belonging to the family Aceraceæ are described. Five of these are completely determined ; the remaining include four leaf species which do not match any modern species in the Himalayas, and one species, *viz., Acer cæsium* based on the fruit. *A. pentapomicum* and *A. villosum*, though occurring in fossil state in Karewas, are absent from the present flora of the Kashmir valley. However, the other two fossil species, namely *A. cæsium* and *A. pictum* are important constituents of its forests and those of the northern slopes of the Pir Panjal.

A comparison of the modern maple forests of Kashmir with those existing here in the Pleistocene period shows that the oaks and laurels, which occurred during the Pleistocene in association with maples, are altogether absent from the valley at the present time. This shows that

[1]The above note has been kindly supplied by the Chief Geologist, Burmah Oil Co. (India Concessions) Ltd.

the climate of the valley has changed since the early Pleistocene times. The present distribution of the fossil species with their associates in the Himalayas is given.

G. S. PURI

* *Lombardy poplar* (*Populus nigra Linn, var fastigiata Desf.*) *in India. Indian Forester*, 71 (*12*) *: 423-425, 1945. With 1 plate.* That in advancing theories on the origin and distribution of species or a plant community it is essential to take palaeobotanical evidence into consideration is illustrated here with reference to the Lombardy poplar. This species is believed by botanists and foresters to have been introduced into Kashmir and other parts of the N.-W. Himalayas in historical times. Its occurrence at Ningal nullah in the Karewa deposits, on the contrary, points out that in this region the Lombardy poplar is at least as old as the Pleistocene period. On the strength of this evidence and that derived from relevant literature it is suggested that the Lombardy poplar is probably indigenous to the Kashmir Himalayas.

G. S. PURI

* *Engelhardtia in the Pleistocene of Kashmir. Ibid.*, 72 (*12*) *: 572-76, 1946. With 1 plate.* A fossil leaflet of *Engelhardtia colebrookeana* is described in detail. It is perhaps the first record of the genus in the Pleistocene. *Engelhardtia* with its numerous species was best represented in southern Europe during the Miocene times; it witnessed a decline during the Pliocene. By the Pleistocene period it had become extinct and is now not represented in the modern flora of this region. On the other hand, while as many as 15 distinct species of the genus are represented in the modern flora of south eastern Asia only one fossil species has so far been discovered from here. The genus thus seems to have been more widely spread during the past than it is today.

G. S. PURI

* *Fossil flora of the Karewa Series. Nature*, 157, *p. 491*, April 13, 1946.

G. S. PURI

**Fossil plants and the Himalayan uplift. Journ. Ind. Bot. Soc. Iyengar Commemoration Volume : 167-184, 1946.* (*Issued 1947*). *With 2 plates.* The author has endeavoured to show in this paper how the testimony of palaeobotany has supported the geologically proved theory of the comparatively recent uplift of the Himalayas. The evidence is drawn from the Liddarmarg flora which flourished in the Kashmir valley during the early Pleistocene. This flora comprised of oaks, laurels, figs, box, alder, *Mallotus*, *Pittosporum*, *Myrsine*, *Rhamnus*, a few water plants (e.g., *Trapa*), and some conifers (*Pinus*, *Cedrus*, etc.). The fossils have been discovered at an altitude of 10,600 ft. on the northern slopes of the Pir Panjal where they are unrepresented in the modern vegetation. On the other hand, a great majority of these fossil species form a dominant feature of the present vegetation at 6,000 to 6,500 ft. These lower regions

receive a heavy rainfall during summer months and experience a tropical climate. The Kashmir valley, which is cut off on the south from the Indian mainland by the lofty ranges of the Pir Panjal, is inaccessible to the monsoon winds and, therefore, now enjoys a temperate climate. The occurrence of a tropical flora in the valley during the Pleistocene has led the author to conclude that the valley slopes at that time were within reach of the monsoon winds which precipitated their moisture in this region and thus created ideal conditions for the growth of tropical plants. The southern barrier, now represented by Pir Panjal, was much lower in the Pleistocene and the fossil evidence strongly favours the view that the whole of this range has since been uplifted by at least 6,000 ft. For fixing the exact date of this event a microfossil analysis of the varved clays in the Karewas combined with the geochronological methods of de Geer, would render much help.

The Himalayan cycle of orogenies, consisting of three important phases, middle Cretaceous, mid-Tertiary and the Pleistocene, is briefly discussed and it is pointed out that these orogenic movements continued through the post-Pleistocene period. There is evidence to believe that the vertical movement of the Himalayas is still in progress. The chief cause of this uplift if believed to be connected with the drifting of continents on Wegenerian lines.

G. S. PURI

The following papers are now published :—

The occurrence of tropical fig. (Ficus Cunia Buch.-Ham.) in the Karewa beds at Liddarmarg, Pir Panjal Range, Kashmir, with remarks on the sub-tropical forests of the Kashmir valley during the Pleistocene. Journ. Ind. Bot. Soc.*, **26 *(3) : 131-35, 1947. With 1 plate.*

**Some fossil leaves of Mallotus philippinensis Muell, from Karewa beds at Laredura and Liddarmarg, Pir Panjal, Kashmir. Ibid. : 125-129, 1947. With 1 plate.*

**Some fossil leaves of Berberis from the Karewas of Kashmir. Ibid. : 177-182, 1947. With 1 plate.*

**Some fossil leaves and fruits of the Common Himalayan ivy (Hedera helix L.) from the Pleistocene of Kashmir. Ibid. : 137-41, 1947. With 1 plate.*

G. S. PURI

A preliminary note on the Pleistocene flora of the Karewa formations of Kashmir. Quart. Journ. Geol. Min. Met. Soc. Ind.*, **20 *(2) : 61-66, 1948. With 2 plates.* The flora comprises of at least 130 species distributed among 70 genera and 34 families of the flowering plants. These are mostly trees or shrubs ; some herbs and water plants are also recorded. Most of them are represented in the modern vegetation of the north-western Himalayas. A large number of the species, *e.g.*, oaks, laurels, figs, *Mallotus*, box, *Pittosporum Myrsine*, etc. which must have been prominent in the valley during the Pleistocene no longer occur in this region. This indicates that climatic and edaphic conditions in the valley have

considerably changed since the early Pleistocene. The change in climate was presumably brought about by the glaciation and uplift of the Himalayan ranges, especially the Pir Panjal, which according to Palaeobotanical as well as geological evidence seems to have been uplifted by at least 5,000-6,000 ft. With the uplift of this region the deposits at the bottom of the Karewa lake were also carried up the sides of the mountains.

The Karewa flora can be divided broadly into three classes : (i) *The Liddarmarg flora* whose constituents, conifers excepted, are no longer found in the Kashmir valley, but are common on the outer Himalayas at 4,000-6,000 ft. (ii) *The Laredura flora* including fossils from Dangarpur, Gogajipathri and Nagbal. Some of the species from this flora still occur in the valley, while others are common in the forests of the outer Himalayas. This flora is a mixture of the Liddarmarg and Ningal nullah types. (iii) *The Ningal nullah flora* which still flourishes in forests of the Kashmir Himalayas at altitudes of 7,000-9,000 ft.

The first two floras indicate a tropical or sub-tropical climate with abundant monsoonic rainfall, while, the third flora seems to have occurred in a temperate climate. Besides this, the edaphic requirements of the three floras are also different. De Terra and Paterson are of the opinion that the three floras occurred during the first interglacial period ; but on the evidence here presented it seems likely that they belong to two or more interglacial periods.

G. S. PURI

QUARTERNARY

Mexico—**A silicified palm fruit from Mexico, Manicaria Edwardsii sp. nov. Journ. Ind. Bot. Soc. Iyengar Commemoration Volume : 327-329, 1946.* (*Issued 1947*). *With 1 plate.* The species is based upon a silicified internal cast kept in the Natural History Museum, South Kensington (London). The locality is given as San Adres, Zantla, district of Etla, Oaxaca, Mexico. No fossil palm has so far been recorded from this country. The present species is also the first undoubted record of the genius *Manicaria* in fossil state. Our specimen is a tricarpellary drupaceous fruit in which only one carpel is fully formed. The main body of the fossil represents the endocarp, the outer coat being preserved only at one corner. The epicarp is represented by a small patch of tissue on one side. The vertically running veins of the inner mesocarp are represented by furrows on the endocarp. The epicarp shows closely placed blunt pyramidal spines on the surface.

K. N. KAUL

SUB-RECENT

Behar, Partabpurnagar—*Angiospermic leaves from Partabpurnagar.* A few badly preserved plant fragments collected by M. K. Roy Chowdhury from a bed of carbonaceous shale overlying certain conglomerates north of Partabpurnagar were found to be angiospermous leaves. One of them with indications of parallel vention probably belongs to the

Graminae. On bulk maceration fragments of cuticle typical of the grasses were recovered. The plant remains may be late Tertiary in age or even sub-recent.

K. JACOB

Orissa, Athmallik State—Samples of suspected diatomaceous earth of doubtful age, collected by H. Crookshank from the north bank of the Mahanadi river, north of Baud, were examined. In the several slides prepared only two diatoms were recognised, the rest of the material being composed chiefly of thin, minute angular and irregular flakes of amorphous silica. They probably belonged to some complex and much broken up siliceous skeletal parts of unknown affinity.

K. JACOB

GENERAL

Palaeontology and the Measurement of Geological Time. Cur. Sci.* **16 : *203-206, 1947. BY B. SAHNI.* The article offers suggestions for palaeobotanical research for the use of the Committee on the Measurement of Geological Time in India set up by the Council of Scientific and Industrial Research, Government of India. Fossils are now regarded as trusted guides to geological age, particularly when considered in their natural assemblages in the strata. A zonal sub-division of strata with the help of fossils is already possible and is applicable over wide areas. Latterly the microfossil investigations of sediments has given valuable help to the stratigrapher, *e.g.*, in the exploration for oil and coal. Owing to their wide dissemination in the body of the rock microfossils can sometimes provide an age index, even if small bits of rocks collected at random are examined. Valuable results can be obtained by applying methods of microfossil analysis to the study of metamorphosed sediments, sediments of disputed or unknown ages, and those associated with igneous intrusions. Palaeontology, however, can give us only a relative measure of geological time ; for its absolute measure recourse must be had to physical methods such as radio-active determination of the minerals composing the rocks. Varved Pleistocene sediments, on the other hand, have been precisely dated by de Geer and his co-workers by counting the varves backwards.

In India there are several stratigraphical problems to which the palaeobotanical method can be profitably applied : (1) Deposits of controversial age such as the Cuddapahs, Vindhyans, pre-Carboniferous strata of the Himalayas, upper Gondwanas of Coromandel coasts, etc. (2) Study of age levels of different horizons of the Deccan trap lava pile. (3) The investigation of the age of the *Cardita beaumonti* beds. (4) Geochronology of the Pleistocene deposits of Kashmir.

R. V. SITHOLEY

**Micropalaeontology in Geology. BY B. SAHNI. Review of " Principles of Micropalaeontology " by Martin F. Glaessner. Nature* 167*, p. 771, 1947.*

**Some aspects of earth history as revealed by fossils. Kashi Vidyapitha Silver Jubilee Comm. Vol.: 1-27. With 13 text figures. BY B. SAHNI.* The article shows how the sedimentary strata of the earth's crust have been formed and how their fossil remains can help us in visualising the course of evolution, in the dating of rocks, and in the reconstruction of geological history. Microfossils can be of value even where the geology is disturbed and they are of much help in the correlation of strata, not only for scientific interest but also for such economic purposes as the search for oil and coal. Recent microfossils studies have proved the existence of a great southward overthrust in the Salt Range, of Cambrian strata over the saline series which contain traces of oil. While a number of geologists have believed the saline series to be of a lower Cambrian or pre-Cambrian age, the author and his co-workers have found it teeming with early Tertiary microfossils, both plant and animal, to the decomposition of which the oil in the seepages and the kerogen shales must no doubt be traced. The curious hair pin bend of the river Jhelum at Domel in Kashmir is most probably connected with the Salt Range overthrust ; the abrupt southward course of the river from this place probably follows a hidden fault plane which may have formed the eastern edge of the thrust sheet of the Potwar plateau moving southward.

R. V. SITHOLEY

**Prospects of Palynology in India. Svensk Bot. Tidskrift. 42 (4) : 474-477, 1948. BY B. SAHNI.* Like any other country India has a wide scope for palynological studies. There is need for sustained critical work, but some significant results have already been achieved. Several geological formations which were long regarded as unfossiliferous (*e.g.*, the Blaini boulder bed, the bottom shales of the Talhcir Series, and the Tertiary oil bearing formations of Assam) have yielded spores and pollen. These discoveries have thrown light upon disputes relating to geological age and structure, on the climatic relations of the *Glossopteris* flora, and on problems of correlation connected with the quest for oil. Where a rich megafossil flora is already known, as in the lower Gondwanas of India, microanalysis has added a surprising variety of spores of pollen forms. This has greatly enriched previous ideas on the composition of the *Glossopteris* flora in the country. Intensive studies of these microfossils, if treated on statistical lines, horizon for horizon and locality for locality, would help to correlate at least some of Gondwana strata with their associated leaf remains.

Other horizons to which microfossil investigation can be applied with advantage are tillites from the lower Gondwanas, the fresh water shales, sandstones and conglomerates of the Siwalik system (Miocene-Pliocene), and the Pleistocene Karewa beds of Kashmir. The boundary between the Siwaliks and the Karewas in Kashmir is difficult to recognise, but may become apparent with the help of pollen analysis. The geochronological method can be applied to varved lacustrine clays which occur on the north-eastern slopes of the Pir Panjal and on the western slopes of the Himalayas. Thus it might be possible to correlate the glacial and interglacial history of Scandinavia with the ice age in northern India. A palynological study of the late Pleistocene terraces may be

helpful for the closer dating of the orogenic movements in northern India. In the same way post glacial peats and lacustrine oozes may be examined for gaining an insight into the way the modern vegetation map of India has emerged from that of the Pleistocene. Of much archæological interest would be the pollen investigations of stratified mounds in India in which successive cultures of pre-historic and historic of man lie buried.

R. V. SITHOLEY

A petrified forest in Central India. Petrified forests such as those of the U.S.A. and other parts of the world are rare in India. It would, therefore, be interesting to record here the existence of an extensive petrifaction of trees *in situ* over a large area in Deola-Chirakhan, Central India. The locality was first visited by the author in company of Chiplonkar in 1935. The forest as a whole, it seemed, had become petrified, and huge tree trunks, often with branches lay strewn in the area. Some of the tree-strumps were still erect in their original positions. The fossilised trees are, to all appearances, dicotyledonous. The basement rocks, largely limestones belonging to the Bagh beds, are irregularly covered by a thin layer of trappean ash beds. These volcanic ashes appear to have enveloped the forest and brought about the petrification and preservation of the sturdy woods of the early trappean period. The area can be approached from Dhar, about 40 miles west of Indore.

K. P. RODE

MICROFOSSIL INVESTIGATION FOR THE MEASUREMENT OF GEOLOGICAL TIME

R. N. Lakhanpal and D. C. Bhardwaj have been engaged in a microfossil investigation for the Committee on the Measurement of Geological Time in India under the Council of Scientific and Industrial Research, New Delhi. This is another attempt to harness palaeobotany to the aid of stratigraphy in estimating the age of rocks. It has frequently been seen that sedimentary strata, which seem apparently to be quite unfossiliferous and therefore useless for palaeontological correlation contain a rich microflora which can be of value in the assessment of their ages. Samples have so far been analysed from : (*a*) *Vindhyans*, (*b*) *the Salt Range*, *Punjab* (shale from the lower part of the Purple sandstone, salt pseudomorph shale, Magnesian sandstone, and the Neobolus beds) ; (*c*) *Deoban limestone*, (*d*) *Tanawals ;* (*e*) *the Blaini beds*, *from Simla and Nepal ;* and (*f*) *Rajmahal Series.*

DISCUSSION ON THE NOMENCLATURE AND CLASSIFICATION OF FOSSIL POLLEN AND SPORES

The first scientific meeting of the Palaeobotanical Society was held at Lucknow on 22nd January 1949 in the Institute of Palaeobotany with B. Sahni in the chair. The object was to discuss the problem of devising a generally acceptable scheme of naming and classifying spores and pollen. The following palaeobotanists participated in the discussion :—

D. C. Bhardwaj, M. N. Bose, and J. Hsü (Lucknow) ; K. N. Kaul (Kanpur), R. N. Lakhanpal (Lucknow), K.R. Mehta (Banaras), and G. S. Puri (Dehra Dun); A. R. Rao and S. R. N. Rao (Lucknow) ; K. P. Rode (Nagpur), S. D. Saksena (Rewa), and V. B. Shukla (Nagpur) ; R. V. Sitholey, G. S. Tewari, B. S. Trivedi, C. P. Varma (Lucknow) ; and S. Venkatachary (Surat).

EXCURSIONS

Behar, Rajmahal hills.—In January 1948 D. D. Pant visited the Rajmahal hills with a small party and brought back an interesting collection of fossil plants. B. Sahni, S. R. Narayan Rao, Jen Hsü, and R. V. Sitholey visited the following localities between 20th December 1948 and 1st January 1949 : Onthea, Tinpahar, Brindaban, Amarjola, Kulkipara, Dumaria Jangli (near Amarapara), and Nipania. A large amount of fossil material was collected, especially from Nipania, the locality of the Pentoxyleæ. From Amarjola (G. V. Hobson's locality) many specimen of *Williamsonia* flowers were obtained.

Specimens of *Gangamopteris*, *Glossopteris*, and *Vertebraria* were collected from the Barakars (Lower Gondwana) exposed on the bank of the Bansloi river, near the Pachwara pass, about four miles west of Amarapara.

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VENKATACHARY, S., M.SC., Ph.D., Head of the Biology Department, Maharana Bhupal College, *Udaipur.*

NOTES FROM THE BIRBAL SAHNI INSTITUTE OF PALÆOBOTANY

The foundation stone of the new building of the Institute was laid on the 3rd April 1949 at 6 p.m. by Pandit Jawaharlal Nehru, Prime Minister of India and Minister for Scientific Research. Symbolical of the science to which the Institute is dedicated, the foundation stone was made from an assortment of plant fossils and rock specimens, representative of many countries and of many ages, ranging from the most ancient to historic times, embedded in a matrix of cement and marble chips. The specimens were either collected by workers in India or came as presents to the Institute from colleagues in different parts of the world. They represented discoveries both of palæobotanical interest and of geological significance and importance in economic geology. The trowel used by the Prime Minister had as its handle the twig of a fossil tree from Patagonia. The construction of the building is expected to begin in a few months time.

At the request of the members of the Governing Body, in its special meeting held on 11th April 1949, the President, Mrs. Savitri Sahni, co-Founder of the Institute, assumed the administrative powers of the Director.

It is planned to bring out the first issue of our journal " The Palæobotanist " in the form of a volume commemorating Professor Sahni.

The following is a list compiled from his MSS and notes, of the investigations with which Professor Sahni was occupied during his last days :

Gondwana microflora ; morphology of *Cyclanthodendron Sahnii ;* studies on *Tubicaulis solenites* and other spp., *Ankyropteris scandens, Psaronius* and its epiphytes ; studies on *Nipadites, Sausarospermum Fermori*, and fossil cardamomum from the Deccan intertrappean beds ; angiosperm leaf impressions from the Kasauli beds (N. W. Himalayas) ; remains of Psilophytales from Spiti (N. W. Himalayas) ; the Pentoxyleæ (Rajmahal hills) ; and a review of palæobotanical research in India.

EXPLANATION OF PLATES

Plate 1

1. Cuticle of *Phyllotheca Etheridgei* Arber from Australia. (× 400).
2. Cuticle of *Phyllotheca striata* sp. nov. from Rewah. (× 390).
3. Megasporangium of *Stauropteris burntislandica* P. Bertrand, showing a spore with a triradiate mark, from Scotland. (× 93).
4. *Ptilozamites Chinensis* sp. nov. from the Rhaetic of China, showing a typically bifurcated rachis. (× 3).
5. A dicotyledonous leaf from Lunu (Barmer sandstone). (× 1).

6, 7. Spore types from the Barmer clay. (× 550).

8. *Palmocarpon insigne* sp. nov. from the Deccan intertrappeans showing parts of the drupe. (× 4½).
9. Leaf of *Cyclanthodendron Sahnii* (Rode) Sahni and Surange from the Deccan intertrappeans. (× 1½).
10. A spicule of *Acicularia* from a chert of the saline series showing spores arranged along the periphery. The outline of the spicule is badly preserved and is indicated by dotted line. (× 67).
11. A group of rounded bodies, probably, blue-green algae, found lying on the wall of a spore from the Pali beds of Rewa. (× 340).
12. Alga-like bodies in fig. 11 further magnified. (× 1080).

Plate 2

13. A fruit-bearing axis with six locular fruits from the Deccan intertrappeans. (× 1).
14. Sectional view of the specimen in fig. 13 at two levels. (× 1).
15. A multilocular fruit from the Tertiary beds of Sagar. (× *ca*. 2).
16. Dicotyledonous leaf from the Deccan intertrappeans. (× *ca*. 3).

17-19. Fossil dicotyledonous wood from the Deccan intertrappeans. 17, transverse section (× 220) ; 18, tangential section (× 150) ; 19, radial section (× 500).

20, 21. Microfossil types from the Deccan intertrappean cherts. 20 (× 400); 21 (× 300).

PLATE 1

1. (X400) 2. (X390) 6. (X550) 5. (X1) 11. (X340) 4. (X3) 7. (X500) 12. (X1080) 3. (X93) 8. ($X4\frac{1}{2}$) 9. ($X1\frac{1}{2}$) 10. (X67)

PLATE 2

13. (X1)

14. (X1)

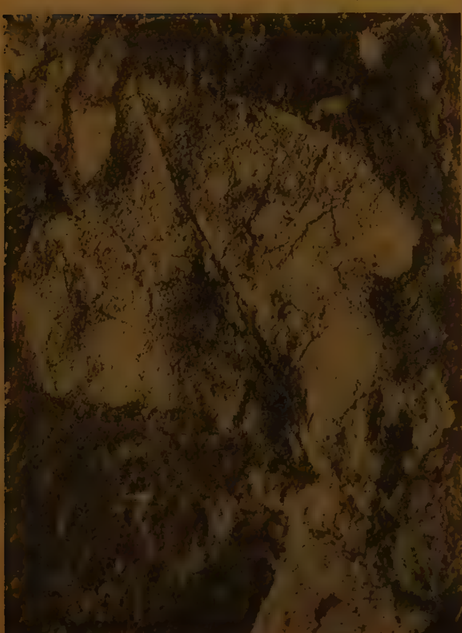
15. (Xca. 2)

20. (X400)

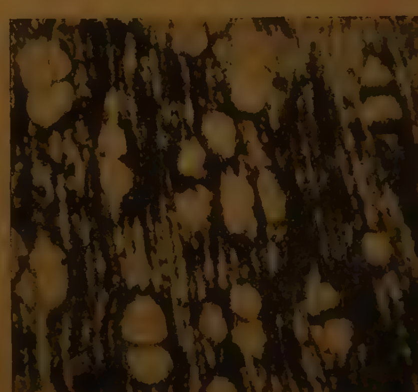
21. (X300)

18. (X150)

19. (X500)



16. (Xca..3)



17. (X220)

THE OCCURRENCE OF PERSISTENT POLLEN TUBES IN *HYDRILLA*, *OTTELIA* AND *BOERHAAVIA*, TOGETHER WITH A DISCUSSION OF THE POSSIBLE SIGNIFICANCE OF THIS PHENOMENON IN THE LIFE-HISTORY OF ANGIOSPERMS.

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(*Received for publication on September* 17, 1949)

During the course of some work undertaken in this laboratory on the embryology of the Hydrocharitaceae, the writers found that in two species, *Hydrilla verticillata* and *Ottelia alismoides*[1], the pollen tubes do not wither away and disappear after fertilisation as in the majority of angiosperms but persist for a considerable time afterward and are sometimes recognisable even in the mature seed. This will be clear from a reference to figs. 1–4. Recently a similar behaviour of the pollen tube was observed in *Boerhaavia diffusa*[2] (figs. 5, 6) and it might perhaps be a more common feature in angiosperms than has hitherto been believed to be the case.

The question arises as to what may be the possible significance of this persistence of the pollen tube long after its normal function, *i.e.*, fertilisation, is over. Is it a haustorial structure which absorbs food substances from the surrounding tissues and transmits them to the embryo, or is it merely a dead organ which persists for a variable period during the maturation of the seed ?

Before attempting to answer this question it seems desirable to review the behaviour of the pollen tube in other plants besides those named above.

It is well known that in the gymnosperms the pollen tube branches and ramifies into the tissues of the nucellus. In some genera like *Pinus*, where 12–13 months elapse between pollination and fertilisation, it is obvious that the food stored within the pollen grain would be insufficient for supporting the growth of the pollen tube for such a long period and that it must absorb food from the cells between which it passes in order to reach the egg. In angiosperms branching pollen tubes, although not unknown[3], are relatively infrequent. However, there is no reason to doubt that here also the growth of the tube is supported by the

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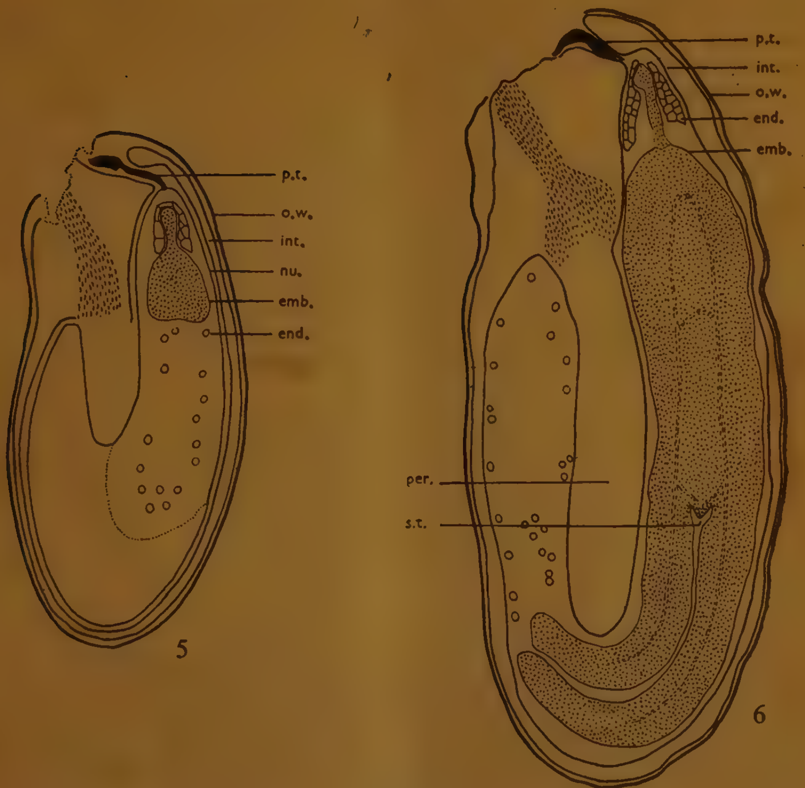
[1] It is possible that this phenomenon is also found in other members of the family but so far our observations are confined to *Hydrilla* and *Ottelia* only.

[2] Kajale (1938), who made a detailed study of the development of the embryo and seed in *Boerhaavia*, makes no mention of this peculiarity.

[3] Branching pollen tubes are found in certain members of the Amentiferae (for literature citations see Maheshwari, 1950).

Fig. 1. *Hydrilla verticillata*, l.s. ovule showing entry of pollen tube inside the embryo sac ; the two male gametes and the tube nucleus are seen in the tip of the tube x 415. Fig. 2. Same, l.s. micropylar part of ovule showing well-developed embryo and persistent pollen tube. x 190. Fig. 3. Same, l.s. mature seed in which remnants of the pollen tube are still seen at the micropylar end. x 190. Fig. 4. *Ottelia alismoides*, l.s. upper part of ovule showing persistent pollen tube and a part of the embryo. x 190. (*p.t.* = pollen tube ; *o.i.* = outer integument ; *i.i.* = inner integument ; *emb.* = embryo ; *s.t.* = stem tip).



Figs. 5-6. *Boerhaavia diffusa*, l.s. fruits showing pollen tubes in the micropyle. × 190. (*p.t.* = pollen tube ; *int.* = integument ; *emb.* = embryo ; *s.t.* = stem tip ; *o.w.* = ovary wall ; *nu.* = nucellus ; *end.* = endosperm ; *per.* = perisperm).

absorption of food materials from the transmitting tissue[4] of the style, the obturator (when present) and the integumentary cells lining the micropylar canal[5].

A very peculiar case of parasitic pollen tubes was recorded by Cook (1909) in some material of *Passiflora adenophylla* collected from a botanical garden in Cuba. Although several ovules showed normal fertilisation, in most cases the pollen tube did not discharge its contents but forged its way onward into the embryo sac becoming greatly twisted and twined in the process. Sometimes its growth was so vigorous that all the contents of the embryo sac were obliterated and the whole cavity filled with the convolutions of the tube. A few years later Cook (1924) noted a similar

[4] The term "transmitting tissue" (Thomas, 1934) is preferable to the more commonly used "conducting tissue."

[5] In *Grevillea* (Brough, 1933), *Berkheya* (Gelin, 1936), and *Cynomorium* (Steindl, 1945) the cells lining the micropylar canal become mucilaginous or glandular.

phenomenon in an ovule of *Crotalaria sagittalis*. He regards these as examples of a parasitisation of the male gametophyte on the female and we are in agreement with this opinion.

It has also been suggested that the pollen tube may sometimes serve as an haustorial organ, not for its own benefit but for that of the embryo sac or embryo. Longo (1904) believes this to be the case in *Cucurbita pepo*. He found that owing to the cutinisation of the walls of the nucellar epidermis and the formation of a suberised hypostase, the embryo sac of this plant becomes cut off from the usual sources of its food supply. The pollen tube is said to compensate for this deficiency. As it approaches the embryo sac, it expands into a large swelling or " bulla " which gives out a number of branches. One of these penetrates the embryo sac and affects fertilisation, while the others ramify into the tissues of the nucellus and inner integument absorbing food material from them and transmitting it to the embryo.

A somewhat similar condition has been reported in certain members of the Onagraceae (Werner, 1914 ; Täckholm, 1915). The pollen tube becomes greatly broadened in the micropyle and often sends out branches into the outer integument and the nucellus, while the tip continues to grow towards the embryo sac destroying the cells in its path. The tube is recognisable until the embryo sac has attained a fairly large size and is presumed to absorb food materials from the surrounding tissues and transmit them to the embryo.

To cite a few other examples, in *Galinsoga ciliata* (Popham, 1938) the tip of the pollen tube is recognisable up to the seven-celled stage of the embryo, in *Ulmus americana* (Shattuck, 1905) up to the 20-celled stage, and in *Carica papaya* (Foster, 1943) for about eight weeks after fertilisation. In *Oxybaphus* (Cooper, 1949)[6] it persists throughout the development of the seed and is believed to transport nutritive materials from the secretory cells of the funiculus to the embryo.

Summarising, it may be said that although there are only a few records of persistent pollen tubes, most of the authors who have observed this peculiarity conclude that in such cases the tube has an haustorial function and transmits food material from the nucellar, integumentary, or other adjacent cells to the embryo.

A careful study of our material of *Hydrilla*, *Ottelia* and *Boerhaavia* gave no evidence in favour of this interpretation. Up to the time of fertilisation the pollen tubes showed their usual nuclear and cytoplasmic contents, but after the discharge of the nuclei the tubes stained densely and homogenously without the least indication of any functional activity. In post-fertilisation stages the tubes did not show any nucleus and the cytoplasm took a uniform stain (red with safranin and black with hæmatoxylin) without any differentiation whatever. This is contrary to what is seen in the haustorial structures derived from the endosperm or the suspensor. In the latter, the cell or cells performing a haustorial function usually show a hypertrophied nucleus and active cytoplasm.

[6] Rocén (1927) also recorded a persistent pollen tube in *Oxybaphus* but makes no comment on its possible significance. It may be presumed that he did not consider it to have a haustorial function.

It seems to us that the supposed haustorial activity of the pollen tube in post-fertilisation stages, whereby it acts as an intermediary for conveying food from the tissues of the old sporophyte to the newly formed embryo, is an inference based solely on the persistence of the tube.

The best way to decide this ~~point would of course~~ be to study living ovules and to see whether the persistent pollen tubes of the plants cited above show any streaming cytoplasm or other evidences of life. This we have not been able to do in our material but from the present evidence as far as it goes it may be concluded that the tubes die soon after fertilisation although their dead remains may be seen in the micropyle for a long time.

no — it is another [illegible]

Summary

The pollen tubes of *Hydrilla verticillata*, *Ottelia alismoides* and *Boerhaavia diffusa* frequently persist in the micropylar part of the ovule for a long time after fertilisation. Several authors have suggested that such persistent pollen tubes serve as haustoria which convey food materials from the adjacent tissues of the ovule to the embryo. Evidence is presented to show that this view is erroneous.

N[illegible]

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STUDIES IN CROP PHYSIOLOGY

Growth, water relation and nutrition of Turmeric plant

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Introduction

Turmeric is an important crop, the rhizomes of which are used as condiments, as an article of daily use, as an essential ingredient in indigenous medicinal preparations, as an ointment for better complexion and various other purposes such as preparation of turmerol and turmeric paper for indicators. It is evidently grown in the black soils of the Deccan, (4) deltaic areas of Madras, (2,3,5) red soils of Orissa (1) and is also cultivated to a small extent in Assam, Bombay and Central India (4). Very little work however, has been done towards the selection of high yielding varieties and the determination of suitable manures and fertilisers which may be helpful in improving the standards of yield and quality. Still meagre information is available to indicate the extent to which this plant needs water for its development and for withstanding the stresses of atmospheric and soil drought. It is the intention to present in a connected sequence some of the results obtained in these directions.

The lines of enquiry pursued in these investigations consist of (*i*) varietal and growth studies, (*ii*) effects of N, P, and K upon growth characters and yield, and (*iii*) water relations of the plant during various phases of desiccation and wilting. The experiments were conducted under conditions of pot culture and narrate the responses under these specific conditions.

Experimentation

The entire work was conducted in glass house or open field condition in pots. A large number of varieties collected from different parts of India by the late Dr. V. K. Badami, twenty in number, were grown in 11 × 9 inches pots filled with ten kilogramme of carefully pulverised farm soil (sandy loam). In all as many as 150 cultures were maintained during 1944 and 89 during the cropping season of 1945. Each culture was numbered and sown with turmeric rhizomes at 3 inches depth. Pots were arranged in regular rows. Adequate watering, hoeing and weeding were done when required at different periods of life cycle.

Pots were arranged in three groups (*i*) for growth studies (*ii*) for nutrition studies and (*iii*) for water relation studies. In the first two cases no artificial fertilisers were applied. Mulches of leaves were spread over the pots during growing period in these cases to prevent rapid evaporation of water from pots. When plants were 1½ months old, farm yard manure at the rate of half cart load for 100 pots was applied. In pots maintained for nutritional studies, ammonium sulphate, calcium hydrogen phosphate and potassium sulphate in required doses were applied.

Procedure and plan of experiments :

Expt. 1. *Varietal Studies on growth and development.*

Varieties :

1. Banaras local
2. Saharanpur
3. Pusa Harda
4. Pusa Hardi
5. N.W.F.P.
6. Katni
7. Chindwara, C.P.
8. Bhagalpur
9. Bilaspur
10. Ranchi
11. Shillong Lashien
12. Shillong Lakkadang
13. Madras
14. G. Udayagiri
15. Travancore
16. S. J. Hora local
17. Basim
18. Ceylon
19. Malaya
20. Cochin.

Total number 20.

Number of cultures : 140 in 1944 ; 57 in 1945.

Medium of growth : Sandy loam soil.

Sowing : 25th June 1944 ; 20th July 1945.

Harvesting : 8th Jan. 1945 ; 25th Jan. 1946.

Observations recorded : (1) Number of green leaves, (2) size and area of fully expanded leaf, (3) number of shoots per plant, (4) height of plant, (5) air dry weight of shoot and root including rhizomes, (6) number of fingers, (7) length and girth of fingers, (8) cured yield of rhizomes, and (9) water storing tubers.

For curing rhizomes were cut into convenient pieces and boiled for 6-8 hours. A small quantity of cowdung was added to enable softening rapidly. When soft to touch at the core, cold drawn tamarind water was smeared over the softened rhizome. These were subsequently dried in sun for ten days. Cured yield of dried rhizomes was recorded.

In some varieties for instance Saharanpur, Pusa Hardi, Katni, G. Udayagiri and Ceylon, fleshy water storing tubers were also prominently developed. Characteristics of such tubers and also colour variations in certain varieties, *e.g.*, Madras, Ceylon and Malaya were recorded. Morphological characters such as height of the plant, leaf number, shoot number and leaf size were recorded at six stages in the life cycle.

Expt. II. *Water relation studies*

Variety Banaras Local was selected for investigation on the effects of desiccation and wilting upon the water relation of the plant. The rhizomes were raised in pots in a manner similar to that described under varietal studies. As many as ten pots were utilised for desiccation and wilting studies in the first year of the experiment and eight only during the second season.

Soil desiccation and wilting effects were measured at three stages of 105, 140 and 187 days in 1944–45. For measurement of transpiratory losses during successive stages of soil desiccation and wilting, only a limited number of four pots were used. The initial moisture percentage was determined on oven-dry weight basis at 105°C and the required quantity of water was added to raise the initial moisture content to 25 per cent on average dry weight basis of the soil. When this was done, two of the experimental pots were sealed all round with a thick coating of bees wax —vaseline mixture. The third pot was similarly prepared and used as control. To start with, moisture was raised to 25 per cent level in all the

three cases. In the first two, moisture depleted was never made good till the plants wilted. In the third, control set, the amount of water lost during transpiration was regularly added to bring the water in soil to original level. All experimental pots were kept inside the glass house and weighed at the end of 24 hours to determine losses, if any. Measurements of losses due to transpiration were recorded for such duration as the plants took to permanently wilt. All values have been expressed in terms of loss per unit dry weight of entire plant or plant organ and also in terms of loss per 1000 sq. cm. of transpiring surface.

Soil moisture at permanent wilting was determined by oven drying at 105°C. The area of leaf surface was traced and total transpiring surface determined on attached plant. Dry weight of plant and plant organs was estimated towards the close of the experiment. Meteorological records of humidity, wind velocity, air temperature and soil temperature were taken every day. The general growth behaviour of plants at successive stages of wilting was also noted.

Expt. III. *Nutritional Studies*

Variety : Banaras local

Treatments : All combinations of

$$\left.\begin{matrix} N \\ N_0 = \text{No manure} \\ N_1 = 80\ \text{ppm. N} \end{matrix}\right\} \times \left\{\begin{matrix} P \\ P_0 = \text{No manure} \\ P_1 = 40\ \text{ppm. } P_2O_5 \end{matrix}\right\} \times \left\{\begin{matrix} K \\ K_0 = \text{no potash} \\ K_1 = 40\ \text{ppm. } K_2O \end{matrix}\right.$$

Total number of treatments 2 × 2 × 2 or 8

Number of cultures : 32

Medium : Farm Soil (Sandy loam)

Fertiliser application : at planting

Sowing : 20th July 1945

Harvesting : 25th January 1946.

Observations recorded: (1) Height, (2) Shoot number, (3) Leaf number, (4) Size of leaves, and (5) Yield of rhizomes.

Effect of fertilisers on growth was recorded in a manner similar to that described under Experiment I.

Experimental Findings

1. *Growth characters of turmeric varieties*

The relative yield of about twenty turmeric varieties was estimated under the local conditions in pots. From the statement presented in Table 1 it is apparent that variety Katni maintained largest number of shoots and yielded highest. Shillong Lashien was equally good in this regard. N.W.F.P. which exhibited few shoot number produced lower yield as well. From the point of view of shoot length, however, this variety was tallest while Cochin and Madras were the shortest. Chief amongst the medium yielders were Pusa Harda and Saharanpur. Some sort of inverse relationship was noted between height and tillering: thus N.W.F.P. which showed few shoots at harvest possessed the greatest height. Katni on the contrary, having the largest number of shoots exhibited lesser shoot length (Table 1).

Table 1

Yield and growth characters of turmeric varieties at harvest.

Varieties.	Shoot wt. gm.	Root wt. gm.	Fingers No.	Height cm.	Leaf length.	Leaf width.	Shoot No.	Leaf No.
Banaras	7·6	68·3	5·7	62·3	29·25	10·0	1·75	5·50
Saharanpur ..	13·15	83·0	5·0	64·65	30·0	10·25	1·50	4·75
Pusa Harda ..	10·5	87·5	4·5	72·40	30·0	10·25	1·75	4·50
Pusa Hardi ..	7·8	87·0	6·0	58·5	30·25	11·25	1·75	6·0
N.W.F.P. ..	7·2	60·3	3·3	77·2	30·25	11·25	1·50	6·5
Katni	11·1	93·5	4·5	64·8	31·5	11·75	3·0	5·0
Chindwara ..	7·5	61·2	3·8	72·15	30·0	10·25	2·0	5·0
Bhagalpur ..	13·9	63·0	5·5	57·15	30·0	10·25	1·75	4·5
Bilaspur	16·1	63·3	7·0	58·4	28·75	9·0	2·0	4·25
Ranchi	10·3	77·0	4·3	66·43	30·25	10·25	2·5	5·75
Shillong L. ..	11·4	78·0	4·7	62·4	29·75	10·5	1·5	6·0
Shillong Lsh. ..	11·1	92·5	5·0	65·83	29·3	8·6	3·0	6·2
Madras	12·2	60·0	3·3	48·2	30·0	10·0	1·75	6·2
G. Udayagiri ..	12·6	57·0	2·3	70·16	29·0	9·0	2·0	6·5
Travancore ..	13·0	62·3	3·8	56·15	29·25	10·0	1·75	7·0
S. J. Hora ..	10·5	31·8	3·5	61·8	31·5	12·0	2·75	6·25
Basim	9·4	45·5	2·5	58·2	29·5	10·5	1·50	6·5
Ceylon	14·4	63·3	2·7	63·3	31·5	12·0	2·25	5·0
Malaya	11·4	70·8	3·0	54·5	29·25	10·75	1·75	5·75
Cochin	17·5	65·8	4·2	47·1	32·25	12·75	1·50	4·50

None of the varieties showed a steady growth with regard to leaf production. Some varieties for instance Pusa Harda, Malaya and Ranchi produced quite a good number of leaves during early stages but shed the leaves early in the life cycle. Banaras local which showed the largest leaf number at 150 days showed unsteady development later on. No apparent relation existed between number of leaves and height of varieties or between leaf number and number of shoots. Consistent results were not at all obtained regarding the varieties having best leaf size. Similarly no specific relation was indicated between size of leaves and number of leaves.

So far as yield of rhizomes was concerned, Katni proved to be the heaviest yielder followed by Shillong Lsh. Yield as judged by the number of fingers did not show any positive correlation with the tillering capacity ; similarly no relation between yield, number of rhizomes and shoot number was found.

In general appearance N.W.F.P., Katni and Pusa varieties exhibited healthy growth, while Travancore, Madras, Basim and G. Udayagiri were the poorest. Varieties from Malaya, Madras and Cochin possessed orange coloured rhizomes while rest showed yellow rhizomes.

The order in which five different varieties stand with respect to different growth characters is given below :—

Shoot wt. : Cochin > Bilaspur > Ceylon > Bhagalpur > Saharanpur.
Root wt. : Katni > Shillong Lashien > P. Harda > P. Hardi > Saharanpur.
Fingers : Bilaspur > Pusa Hardi > Banaras > Bhagalpur > Shil. Lash.
Height : N.W.F.P. > P. Harda > Chindwara > Travancore > Sh. Lakh.
Leaf length : Cochin > Katni > S. J. Hora > Ceylon > P. Hardi.
Leaf width : Cochin > S. J. Hora > Ceylon > Katni > P. Hardi.
Shoot No : Katni > S. Lashien > Ranchi > S. J. Hora > Ceylon.
Leaf No : Travancore > N.W.F.P. > G. Udayagiri > Basim > Sh. Lashien.

So far as yield, root weight and leaf size were concerned, Katni showed better performance than other varieties. Cochin was also good from the point of view of shoot development and leaf size. Pusa varieties were good with respect to fingers, height, and leaf size. Shillong Lashien was equally good in yield and also in shoot number, leaf number and finger number. Other varieties did not come up to the standard of growth attained in these forms.

II. *Growth characters as affected by nutrients.*

Comparative effects of eight nutrient combinations—C, N, P, K, NP, NK, PK and NPK on growth characters was studied at four stages of the life cycle. Observations recorded (Table 2) showed that one month after the application of manures, NK proved better than all others ; K was least useful in improving height. At the third stage of observation (90 days) NK again improved height over other fertiliser cultures. P was the poorest in this regard. At the last stage however, NP appeared to be the best. Singly, any one of these ingredients failed to improve vigour. Combinations of P and/or K with nitrogen proved more useful in improving height.

Shoot number was more or less similarly affected. NK proved better at the second and third stages (60–90 days) while NP was superior to others at the third stage only. Treatments lacking in nitrogen such as P and PK were least effective.

NK consistently produced more number of leaves. Phosphorus was least effective. The control and P treated plants showed the least number of leaves at the second and third stages while P fed plants were the poorest at the last stage.

Length of the leaf, however, was improved more by PK, at the last two stages of observation. NP was least effective. On breadth of leaf, the effect of NPK was better than other treatments at second and third stages. At the last period of observation, P proved to be better than others.

So far as yield of rhizomes is concerned, data recorded show that a maximum yield of 106 gms. per pot was recorded under NK as against 71 gms. in control plants (Table 3). Fifty per cent more yield was thus secured in pots by fertiliser application. Potash was poorest in yield and more or less equal to the control. PK and NPK treatments were effective but not to the same extent as NK. Under the same treatment, number of daughter rhizomes was maximum. P showed the least number of rhizomes. Treatments producing the greatest height produced the largest number of fingers. Similarly those inducing greater leaf formation yielded maximum number of rhizomes. No relationship between the number of daughter rhizomes and size of leaf was noted.

Table 2

Growth characters of turmeric plants as influenced by nutrition.

Stage of growth	C	N	P	K	NP	NK	PK	NPK
		A. Height of main shoot						
I ..	20·6	18·3	21·5	18·0	20·4	23·9	21·8	19·7
II ..	34·9	30·9	31·4	29·0	37·5	40·6	36·5	36·4
III ..	32·2	31·1	31·0	34·7	37·8	42·5	36·2	36·7
IV ..	32·6	31·1	31·6	35·9	41·6	39·1	36·5	37·5
		B. Number of shoots per plant						
I ..	2·2	3·2	2·0	2·2	3·0	2·5	2·0	2·0
II ..	3·0	2·8	2·2	2·2	2·8	3·3	1·5	1·7
III ..	2·8	2·2	1·7	2·0	3·3	3·5	2·2	2·0
IV ..	2·2	2·5	2·0	2·2	3·5	3·3	1·7	2·0
		C. Number of leaves per plant						
I ..	3·3	3·3	3·5	3·0	2·5	3·7	3·3	3·0
II ..	5·0	6·0	5·0	5·2	5·7	7·0	6·2	5·2
III ..	5·0	6·0	5·0	5·5	5·5	6·2	5·5	5·5
IV ..	5·2	5·7	4·7	5·7	6·0	6·5	5·2	5·0

Note: Stages I, II, III and IV represent 30, 60, 90, and 120 days in the life cycle.

Table 3

Mean yield of rhizomes and number of fingers under different treatments.

Treatments	Yield in gms.	Number of fingers
Control	71·0	2·7
N	79·2	4·0
P	79·9	3·0
K	71·2	4·2
NP	91·7	5·0
NK	106·0	7·0
PK	95·5	5·5
NPK	85·7	5·5

Table 4

Analysis of Variance (Yield).

Due to	Degrees of freedom	Sum of squares	Mean sum of squares
Blocks	3	20	6·7
Treatments	7	4332	619·0**
Error	21	1241	59·1
Total ..	31	5593	....

S.E. $= \pm 7 \cdot 68$

Table 5

Main Effects and Interaction (Yield).
(Total)

M.E. and Int.	Response
N	188**
P	102*
K	146**
NP	—163**
NK	21
PK	—69
NPK	—191**
S.E.	$\pm 43 \cdot 4$

Statistical analysis of yield data showed treatment effects to be significant (Table 4). Main effects of N, P, and K were all highly positively significant. Interaction between N and P showed negatively significant response (Table 5). Other first order interactions were not significant at all. Higher order interaction was, however, negatively significant. Relatively, nitrogen appeared to be most helpful followed by potash and phosphoric acid.

III. *Transpiration per plant in relation to soil desiccation.*

A comparison of results obtained in turmeric plants points out the existence of a number of phases in the transpiratory drift with advance in desiccation. During initial stages of desiccation, transpiration per plant was usually very high and showed good deal of fluctuation from day to day. During the second phase noted between 12–23 days in plant No. 10, and 12–19 days in culture No. 11, a tendency to reduce transpiration was evidenced with an indication towards attainment of more or less a level phase. The third phase of temporary wilting was characterised by a sudden decline in transpiration to the zero level. This

state of affair continued for a few days when the plant made an attempt to recover during night. The fourth stage of permanent wilting was noted beyond 23 days in culture No. 11 and beyond 28 days in culture No. 10. In each of these cases permanent wilting was preceded by a sudden increase in transpiration and followed by a reduction to the zero level and subsequent death of the plants (Fig. 1).

At 140 days in the life cycle, the behaviour of cultures No. 13 and 14 was quite distinct. These showed in general less marked fluctuations and a lower rate of transpiration. The first phase of ascending transpiratory activity was noted for a very short period in both the cultures. The second phase of declining transpiratory loss was more characteristic. The stage of temporary wilting was preceded by a high transpiratory loss on the 19th day in plant No. 13 and between 15-16th day in plant No. 14 (Fig. 2). This was always followed by declining loss of water for a period of 3-4 days in both the plants. Permanent wilting stage was again characterised by a slight increase in transpiratory activity on 22nd day in culture No. 14 and 23rd day in culture No. 13. Subsequently, drying of the plant took place ; this was always associated with a stationary level in both the cultures.

At 187 days in the life cycle, the first two stages of increasing and decreasing activity though slightly evident on some days was not very characteristic. The third stage of temporary wilting was always preceded by high transpiration loss a day or two earlier and was invariably followed by a fall to the zero level. Permanent wilting was again associated with or preceded by high transpiration in pot No. 6, 11 and 33. In all cases it was invariably followed by a level phase of transpiratory water loss (Fig. 3).

An intercomparison of the stage at which permanent wilting took place showed that the period from the start of the experiment was considerably cut short from 27 to 29 days during early periods to 22-23 days during the second stage and finally between 16-17 days towards the later stages of growth.

IV. *Transpiration per unit weight of root, stem and entire plant.*

When the daily water losses were calculated on the basis of unit weight of roots certain characteristic features were noted with advance in period of desiccation (Fig. 4). Thus at 105 days in the life cycle, a high value for water loss was noted on the 5th day followed by a continuous decline with advance in the period of drying. On the 11th day, water loss reached fairly low values. Subsequently a marked tendency to increased water loss was noted till the 15th day of the experiment. On the 17th day, water loss reached the lowest limit recorded, followed by a period of temporary rise.

At the second stage of observation (140 days) the first phase of undulating transpiratory activity was less evident. Between the 8th and 12th days transpiration values were more or less constant, to be followed by a marked decline between the 12th and 14th day of the experiment. A short durationed rise was noted on the 16th day. In contrast to this, the values recorded at 187 days showed a relatively slower

activity with advance in desiccation upto the 10th day subsequent to which some increase in transpiration per unit weight of the absorbing organ was recorded. In general, the greater the age of the plant the lower were the transpiration rates calculated on root weight basis.

In contrast to the observations recorded above, transpiration per unit weight of shoot showed altogether different effects. During the early stages of desiccation, transpiration losses at 105 days were least and those at 140 days the highest. In between these two limits were noted the rates of transpiration at 187 days. At advanced stage of desiccation such as after the 13th day there was no marked difference between the respective transpiratory losses at 105, 140 or 187 days (Fig. 4).

Transpiration expressed on the basis of unit weight of the entire plant showed variations more or less of the same order as those indicated for the roots. Once again, age of the plant showed a characteristic response. The higher the age of the plant the lower were the rates of water loss. Towards the advanced stages of desiccation however, no marked differences between the values recorded for 140 and 187 days were noted. The data recorded thus point out that age effects were as characteristic in regulating transpiratory losses as the effect of soil desiccation.

V. *Transpiration per unit area of leaf in relation to desiccation.*

At 105 days, the rate of transpiration calculated on the area basis of plants followed the general course of increasing activity upto the 7th day of the commencement of the experiment (Fig. 5). With advance in the period of desiccation subsequent to this period, there was noted a gradual fall with a number of undulations and adjustments. A tendency to constant level phase was recorded between the 15th and the 18th day. In contrast to this, data recorded at 140 days indicate that the stationary phase was noted earlier between 7–12th day preceded by a phase of fluctuating transpiratory activity and followed by a decline which gradually reached a low value on the 20th day.

Transpiration rate at 187 days showed lesser fluctuations during early and late periods of desiccation. The pericd of stationary activity was recorded between the 6th and 8th day of experiment in ccntrast to to the 8–12th day recorded at 140 days.

When transpiration rates per unit area were expressed as percentage of control, the values recorded specifically indicated the effect of soil desiccation on this process (Fig. 5). At 105 days in the life cycle it was noted that this ratio fell down with advance in the period of desiccation upto 5 days. Beyond this, the ratio showed a rise reaching highest values between the 10–11th day of the experiment. A marked decline in ratio was noted after this period of desiccation. At 140 days, however, the ratio showed a steady but slow decline with advance in desiccation. No peak values were recorded so characteristically as the one recorded at 105 days. At 187 days, on the other hand, transpiration ratio showed increasing values between the 4–6th day and thereafter evinced a marked decline with advance in desiccation. A general feature of this transpiration ratio was the steady behaviour with advance in desiccation

particularly at 140 days in the life cycle with a slow decline with time. At other stages the fluctuations were more markedly noted.

When the ratio $\frac{\text{transpiration of experimental plants}}{\text{transpiration of control plants}} \times 100$ was plotted against the calculated values of soil moisture at the three stages of observation, the relationship between the two was very marked (Fig. 6). Each curve could be conveniently divided into three regions (*i*) region of stationary or slowly rising activity, (*ii*) a region of marked decline and (*iii*) a region of increased activity. Taking the first two stages of observation into consideration, 13-15 per cent of soil moisture appeared to be the critical limit below which the ratio showed a continuous increase and above which the ratio indicated a decline. At higher moisture percentages above 17·5 per cent, the ratio always showed a positive and a marked increase at all the three periods of observation. Similarly a fairly low value of this ratio was recorded at 16–17 per cent at two stages (140 and 187 days) and 22 per cent at 105 days in the life cycle. These differential effects of soil moisture were distinctly noted.

VI. *Wilting coefficient of soil as affected by stage of growth.*

At the three stages of growth of turmeric, wilting coefficient of soil was found to be approximately the same (Table 6), indicating thereby that it was not affected to any marked extent by the stage of plant growth. Inspite of the constancy of soil moisture at which wilting of plants took place, the plants required different periods for the complete transference of the fully turgescent stage to the stage of wilting. Doubtless this was related to the conditions of the environment in the first instance, and secondly to the degree of vegetative development and transpiring surface formed by the plant. The evidences recorded indicate in general, that the later the period of growth, the lesser was the time taken by the plants to wilt ; this duration was reduced from approximately 30 days in the first case (105 days) to 25 days in the second (140 days) and finally to 20 days with the final set (187 days). Looking to the low rate of transpiration per unit area towards later stages of growth, this period should normally be extended beyond those recorded during the early stages. But the experimental records prove to the contrary. Similarly the high average transpiration loss per plant during early stages as compared with the average loss recorded towards later periods does not bear testimony to the reduction in the duration of the period of wilting from 30 to 20 days as recorded in these investigations. How and in what way it is related to the formation and development of rhizomes at later periods remains yet to be investigated.

VII. *Transpiration/Dry weight ratio in relation to growth and wilting coefficient.*

The ratio of total transpiration loss during the entire duration of desiccation to the dry weight produced at the close of wilting was worked out at all the three stages of growth of turmeric. At the early stages, this ratio was the highest ; in the middle portion of the life cycle it was medium while towards the later periods fairly low values were obtained. Per unit dry weight, quantity of water lost during various

phases of desiccation was thus more during early stages and gradually lowered with advance in age of the plant; in contrast to this the wilting coefficient of soil did not vary appreciably. High ratio was also related to greater duration of wilting period; low ratio on the other hand was correlated with shorter duration of wilting period (Table 6).

Table 6

Transpiration—dry weight relation at various stages of turmeric.

Age in days.	Duration of desiccation expt.	Total water lost in gm.	Dry wt. of plants in gms.	$\frac{\text{Transpiration}}{\text{Dry wt.}}$	Wilting coefficient.
105	(*i*) 29 days	2463	20·87	118·03	4·14
	(*ii*) 27 ,,	2580	8·89	289·98	4·64
140	(*i*) 23 ,,	2044	23·00	88·87	4·54
	(*ii*) 22 ,,	1938	24·50	79·10	4·42
187	(*i*) 17 ,,	1444	32·00	45·13	4·35
	(*ii*) 16 ,,	1833	41·00	44·70	4·00

VIII. *Relation between dry weight, area of leaf and duration of wilting.*

Dry weight/area ratio at different stages of life cycle showed fairly high values during early stages and relatively low value during the middle period. This indicates that tne efficiency of leaves to add to the plant's substance is high during early stages and low during later periods. The lower the ratio, the lower appeared to be the duration of wilting. This was true for at least two stages of the life cycle (Table 7).

Table 7

Relation between dry weight and area of leaves at three stages.

Age in days.	Duration of experiment in days.	Dry weight gms.	Leaf area sq. cm.	$\frac{\text{Dry weight}}{\text{Leaf area}} \times 100$
105	29	20·87	2363·0	88
	27	8·89	3340·5	375
140	23	23·0	4799·4	48
	22	24·50	5638·6	43
187	17	32·0	5922·0	54
	16	41·0	7433·0	55

IX. *Nutrient effects on water relations.*

Total loss of water per plant under the influence of different fertilisers varied considerably at various stages of the progress of wilting. While the tendency of the plant to lose less and less with advance in stage of desiccation was evident under all nutrients, certain specific differences

between each nutrient culture were noticed. Thus the control plants lost more water than the nitrogen treated ones during early stages (Table 8) ; during later periods of desiccation the reverse was the case. No marked differences between K and P and between NP and NK treated plants were observed. PK treated cultures however, lost more water during transpiration as compared with NPK treated ones during early stages ; during later periods this was not so characteristic. Increase in transpiratory activity at or prior to the commencement of temporary or permanent wilting was noticed in almost all cases.

Table 8

Transpiration per plant under different fertilisers.

Days	N	P	K	NP	NK	PK	NPK	Control
2	139·2	159·6	111·6	97·0	113·7	133·8	50·0	103·4
3	64·4	75·6	76·2	73·6	110·0	150·0	57·0	94·0
4	94·2	111·8	100·0	140·0	26·5	124·4	80·0	100·0
5	94·2	110·8	100·0	20·0	120·0	156·4	20·0	100·0
6	133·0	108·4	120·2	97·6	161·6	90·0	19·4	249·2
7	17·6	157·5	70·2	102·4	132·2	184·4	115·8	197·4
8	15·4	44·3	17·8	81·6	129·8	102·2	22·2	77·6
9	34·4	80·0	4·4	41·2	57·2	23·4	21·7	32·4
10	39·6	91·4	64·6	137·4	123·2	190·0	101·5	209·8
11	21·6	..	38·2	100·0	46·4	120·0	98·5	86·6
12	69·4	..	14·6	175·6	..	99·6	50·7	41·0
13	80·0	..	40·0	144·0	..	100·0	57·0	100·0
14	236·2	113·4	50·0	113·4	226·8	46·4	113·4	60·0
15	67·0	..	151·0	67·0	60·0	180·4	67·0	..
16	37·0	..	..	113·4	..	113·4	46·4	..
17	9·4	..	..	...	..	46·4	..	..

Table 9

Transpiration per unit dry weight of turmeric plants under different fertiliser treatments.

Days	C	N	P	K	NP	NK	PK	NPK
2	4·95	8·59	10·8	5·0	3·6	3·3	4·3	1·6
3	3·7	3·98	5·1	3·4	2·7	3·2	4·8	1·9
4	2·7	3·40	8·1	5·6	5·2	0·8	4·0	2·7
5	3·96	5·81	7·4	4·5	0·7	3·5	5·0	0·6
6	9·87	8·21	7·3	5·4	3·6	4·7	2·9	0·6
7	7·82	1·10	10·6	3·1	3·8	3·9	5·9	3·9
8	3·09	0·95	2·9	0·8	3·0	3·0	3·3	0·74
9	1·29	2·10	5·4	0·2	1·5	1·7	0·75	0·72
10	8·32	2·40	6·1	2·9	5·1	3·6	6·1	3·7
11	3·44	1·40	..	1·7	3·7	1·5	3·9	3·3
12	1·70	4·30	..	0·65	5·5	..	3·2	1·7
13	3·96	4·90	..	1·80	5·3	..	3·2	1·7
14	2·38	14·60	7·7	2·20	4·9	6·7	1·5	3·8
15	...	4·10	..	6·60	2·5	1·8	5·8	2·2
16	..	2·30	..	..	4·9	..	3·6	1·5
17	..	5·80	7·7	..	..	..	1·5	..
18	..	..	4·5	..	2·5	1·5	..	..

Table 10

Transpiration per unit area of leaves in relation to fertilisers.

Days	C	N	P	K	NP	NK	PK	NPK
2	21	46	33	22	36	45	32	16
3	18	21	16	15	27	44	35	18
4	14	18	25	25	31	11	29	26
5	20	31	23	20	67	48	37	6
6	15	44	23	24	36	64	21	5
7	39	6	32	14	37	54	42	37
8	15	5	9	35	3	52	25	7
9	6	11	17	9	2	23	6	7
10	42	13	19	13	49	49	45	33
11	17	7	..	8	36	17	28	32
12	8	23	..	3	65	..	24	16
13	20	26	..	8	52	..	24	18
14	12	79	3	10	42	9	11	36
15	..	22	..	30	25	24	42	21
16	..	12	..	..	42	..	27	15
17	..	3	23	..	..	..	11	..

When expressed per unit weight of the plant (Table 9), the transpiration loss varied less characteristically with advance in period of desiccation. Augmentation in activity at or prior to temporary or permanent wilting was again noticed. After the attainment of the zero level of transpiration there was noticed in case of P and N, NP and control plants, an attempt to regain lost turgidity by absorbing moisture from the atmosphere. This however was only of a transitory nature and did not help materially in maintaining the normal water relation.

On unit area basis again, the facts recorded above were noticed (Table 10). The general decline with age was more characteristic in case of NK, K and control and less so in case of P, NP, PK and NPK. In most of these cases fairly low values were obtained between the seventh and ninth day. This low rate persisted more in case of N and less in other cases. Augmentation in activity prior to wilting was again noticed.

Discussion

The evidences cited in previous pages on various aspects of the problem of water relation, nutrition and growth of turmeric have shown certain outstanding features. Water relation of the turmeric plant unlike most of other species is complicated by the fact that this plant possesses an underground stem which usually stores large quantities of water either in the tissues of the rhizomes or in special water storing tubers. Under restricted moisture conditions in soil, these tissues are likely to part with the water contained in them when the root system failed to supply the demand of the growing plant.

In sealed pots where no possibility of additional supply of moisture besides that contained in the soil itself exists, the plant has to depend upon the moisture contained in soil alone. During early stages of the commencement of desiccation, when moisture content is high and the plant is in fully turgid condition the stresses of the environment help in maintaining a high fluctuating rate of transpiration. This, however, does

not continue for a long time. Sooner or later when soil moisture falls down from a high value of 25 per cent in the beginning to a low value of about 13–15 per cent, the rate of transpiration also reaches a fairly low level. In the early stages of observation a stationary rate is recorded for a shorter or longer period. During this phase, environmental conditions, as it were, were less effective in raising transpiration ; water loss appears to be controlled rigidly by the internal conditions of the plant where considerable forces develop on account of the colloidal and other forces generated under deficient moisture supply and other physico-chemical changes in protoplasmic behaviour regulating water losses from plants.

Sooner or later, this ability to resist water loss and to reduce transpiration to a minimum, is lost. Temporary wilting sets in, preceded by a sudden increase in transpiration and almost immediately followed by a low rate in the subsequent period of permanent wilting. Such phasic rise and fall portrays the limit of resistance offered by the plant to the stresses of the atmosphere on the one hand, and the conditions of deficient soil moisture on the other. The ability of different species to withstand desiccation would no doubt differ mainly on account of structural and functional peculiarities and less so on account of the differential growth requirements at different periods of the life cycle. The latter is evident in the fact that stage of the life cycle does not affect the wilting coefficient of soil to any marked extent. The earlier the age the greater however is the time taken by the plant to be completely desiccated. This may to a large extent be due to relatively high moisture content of the plant tissues and also greater absorption efficiency of the root system. At later stages both these conditions affecting moisture relation are usually reduced with the result that the plant does not take a long duration to change its physiological state from complete turgescence to permanent wilting.

Comparative effects of age and period of desiccation have shown that advance in desiccation brings about marked reduction in transpiration rate per unit area irrespective of the age or the stage of plant growth. The greater the age of the plant the lesser appears to be the diurnal losses at various periods of desiccation. Expressed in relation to the soil moisture content the observations indicate that 13–15 per cent is the critical limit below which there is the general tendency of the plant to exhibit increased water losses within the moisture range of 5 per cent and above. The greater the moisture content within this limit the higher is the rate of transpiration. Above the critical limit of 13–15 per cent, there is noted a characteristic fall in the rate upto a critical maximum of 17. 5–20 per cent. In still higher levels, increase moisture exhibits more or less a state of luxury consumption of water, the rate of transpiration in consequence exhibiting a continuous rise. Data on the climatic conditions show that they are least affective in bringing about changes in transpiration rate at advanced periods of desiccation, though their effects are more evident during early stages. In certain cases a marked tendency for the plants to absorb water from the atmosphere has been noted particularly during the period of incipient wilting. But this has very little significance in the normal water relation of the plants at low moisture contents. Nutrients too have been found to have very insignificant effect upon the moisture content of the soil at which the plant wilts though

growth and development is markedly affected by their supply. The general behaviour of the plant with progress of desiccation remains more or less similar with the characteristic fluctuating phase in the beginning followed by the stationary or the slow declining phase and the stage of temporary increased activity prior to wilting.

Coming now to the question of growth and performance of different varieties of turmeric, recorded data make it possible to group the varieties into three main categories depending upon the extent or degree of growth and yield exhibited by them :

(*i*) High yielding varieties: Katni, Shillong Lashien, Pusa Harda, Pusa Hardi, Saharanpur, Shillong Lakkadang and Ranchi.

(*ii*) Medium yielders : Malaya, Banaras Local, Cochin, Ceylon, Bilaspur, Bhagalpur and Travancore.

(*iii*) Poor yielders ; Chindwara, Madras, N. W. F. Provinces, G. Udayagiri, Basim and S. J. Hora Local.

High yielding varieties show certain improvements in various growth characters at different stages of the life cycle. For instance, high yield has been found related to height and leaf number. Other characters show little relation. No specific relation between yield and magnitude of these characters is however noted. Yield of rhizomes and number of fingers appeared to bear close resemblance. From an economic point therefore varieties belonging to the first category deserve trial under field conditions, where the possibility of further raising the standard of their yield may be profitably investigated. The evidences in pots during two successive seasons show the better performance and yield of these strains.

Among the fertilisers which may profitably be attempted to improve the yield, nitrogen and potash applied together may be recommended. Both these fertilisers show significant effects upon yield in pots. The ratio in which they would be most beneficial under field conditions remains to be worked out.

Summary

The paper deals with the effect of (*i*) nitrogen, phosphorus and potash upon growth characters, (*ii*) soil desiccation upon transpiration and (*iii*) varietal studies on Turmeric plant. Twenty varieties collected from different parts were used for purposes of experiment. The work was conducted in earthenware pots each having a capacity of 10 kgm. of farm soil. Records of growth behaviour, transpiration rate and wilting coefficient of soil were taken at certain specified stages of the age cycle.

Among the most promising varieties may be mentioned Katni, Shillong Lashien, Pusa Harda, Pusa Hardi and Saharanpur. The first of these proved to be the best from yield, root weight, and leaf size points of view. Cochin another good variety proved efficient in shoot development and leaf size.

All the three fertilisers—N, P, and K, proved to be positively significant in effect. Nitrogen was more helpful than potash, and potash more helpful than phosphorus. First order interaction $N \times P$ and higher order interaction $N \times P \times K$ both were negatively significant. A combination of N and K gave highest yield of rhizomes per plant.

Transpiration per plant varied considerably with duration of soil moisture desiccation. In general, plants showed (*i*) a fluctuating phase of transpiration, (*ii*) a stationary phase, (*iii*) a pre-wilting phase of high transpiration and (*iv*) the phase of permanent wilting when transpiration was brought down to the zero level.

The above four phases of transpiration in relation to soil moisture depletion, were characteristically noted at all the three periods of the life cycle. But the time taken by the turmeric plant to change from complete turgidity stage to permanent wilting decreased with advance in age.

Transpiration per unit weight of the entire plant or root showed a characteristic fall with (*i*) advance in stage of plant's life cycle and (*ii*) advance in duration of soil desiccation. Calculated on shoot weight basis, the variations towards advanced stage of desiccation were not so prominent as the variations during early stage of high moisture content. Individual effects have been discussed at length.

On unit leaf area basis, again both age and soil depletion lowered transpiration rate more particularly during the 6–12 days of the progress of wilting. Rise in transpiration rate prior to wilting was noted at all the periods.

Transpiration rate of plants expressed as percentage of control, when plotted against the calculated moisture content of soil show (*i*) a region of stationary or slowly rising activity at low moisture, (*ii*) a region of marked decline under medium moisture and (*iii*) a region of increased activity at high moisture content.

13–15 per cent of soil moisture appeared to be the critical limit below which the ratio showed a continuous increase and above which it indicated a decline. Above 17·5 per cent, soil moisture invariably raised transpiration in plants.

Wilting coefficient of soil was unaffected by the stage of growth of plants. But quantity of water lost per unit weight of plants was more during early stages and gradually lowered with advance in growth period.

Efficiency of leaves to produce dry matter was high during early stages and low during later periods. The lower the dry weight/area ratio, the lower was the duration of desiccation required to wilt the plant.

Addition of fertilisers changed transpiration rate of plants at successive stages of desiccation. Pre-wilting rise was again noted under all fertilisers.

The manner in which soil moisture depletion interferes with the water relation of the plant has been discussed.

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CONTRIBUTIONS TO THE EMBRYOLOGY OF THE LILIACEÆ[1]

I. Development of the Embryo Sac and Endosperm of Albuca Transvalensis Moss-Verdoorn

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(*Received for publication on August* 23, 1949).

Introduction

Members of the family Liliaceæ have always been considered very suitable for embryological and cytological studies because of their large nuclei and the ease with which the material takes the usual cytological stains.

Of special interest is the development of the embryo sac which shows a considerable range of variation in the family. As many as five distinct types have been recorded (Fig. 1) :

1. *Polygonum type.*—Here the four megaspores formed after meiosis form a linear or T-shaped tetrad. Occasionally a row of three cells is formed due to an omission of the second meiotic division in the upper dyad cell. Usually the chalazal megaspore functions but sometimes the other three also begin to divide and in *Gloriosa* (Afzelius, 1918 ; Eunus, 1949a) all four develop as far as the two-nucleate stage. The mature embryo sac is eight-nucleate and shows the typical organisation.

2. *Allium type.*—In all species of *Allium*, which have been studied so far, the embryo sac is bisporic and arises from the chalazal dyad cell. This type is also of frequent occurrence in several other members of the family. Species of the genus *Scilla* (Hoare, 1934) presents a notable variation for here it is the micropylar dyad cell which gives rise to the embryo sac. In *Convallaria majalis* (Stenar, 1941) both the meiotic divisions are accompanied by wall formation, but the walls laid down after the second division soon break down so that we once again get the original dyad cells, each having two nuclei. For a time both continue to grow but eventually the chalazal dyad cell acquires the more dominant position and gives rise to the embryo sac.

3. *Drusa type.*—In *Majanthemum bifolium* (Stenar, 1934) the embryo sac is tetrasporic and the four megaspore nuclei undergo two successive divisions to give rise to 16 nuclei, four at the micropylar end and twelve at the chalazal. The mature embryo sac has a three-celled egg apparatus, two polar nuclei and eleven ephemeral antipodals.

4. *Fritillaria type.*—This type of development, first described by Bambacioni (1928) in *Fritillaria persica*, is characterised by a 1+3

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[1] A preliminary account of this work appeared in the Proceedings of the Indian Science Congress, Allahabad session (Eunus, 1949).

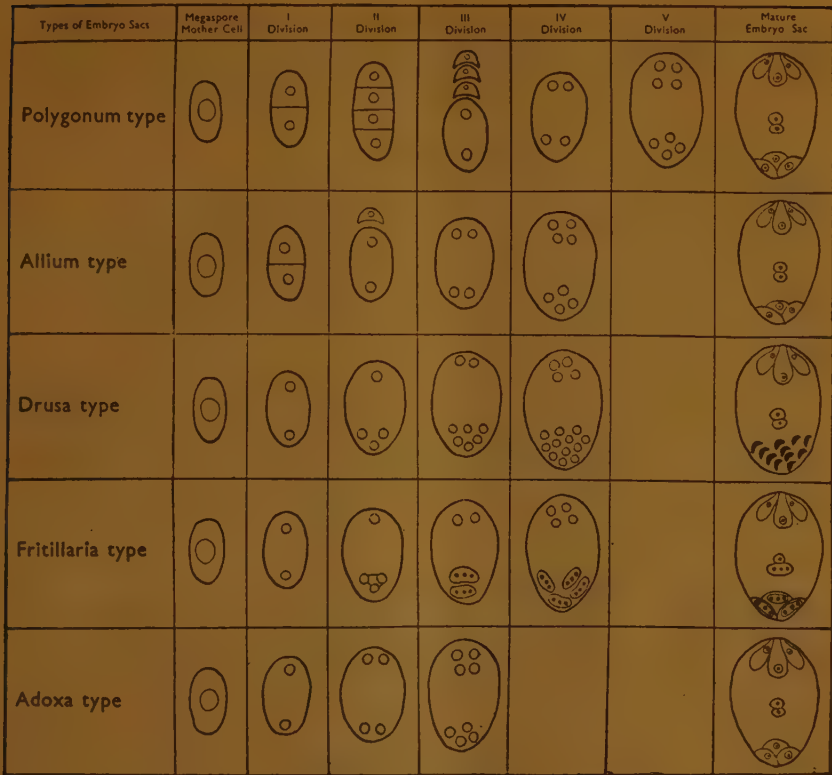

Fig. 1. Types of embryo sac development in the family Liliaceæ.

arrangement of the megaspore nuclei followed by a fusion of the spindles of the three basal nuclei. Consequently, there is an interpolation of a secondary four-nucleate stage with micropylar pair of haploid nuclei and a chalazal pair of triploid nuclei. The next division, which is normal, gives rise to a micropylar quartet of haploid nuclei and a chalazal quartet of triploid nuclei.

The Fritillaria type of embryo sac is characteristic of the sub-family Lilioideæ and some other members of the Liliaceæ (see Maheshwari, 1946). There is often a reduction in the number of divisions at the chalazal end reaching an extreme condition in *Clintonia* (Smith, 1943 ; Walker, 1944). Here the three megaspore nuclei at the chalazal end of the embryo sac begin to degenerate as soon as the meiotic divisions are over. Frequently they fuse in an irregular manner but the fusion product is in such an advanced stage of degeneration as to be unable to take part in further development.

5. *Adoxa type.*—In this case no permanent walls are laid down during the meiotic divisions and all the four megaspore nuclei divide once to give rise to the eight-nucleate stage. This type of development is known in the family only in *Erythronium albidum* (Cooper, 1939) and *E. americanum* (Haque, 1949).

An interesting variation of the above occurs in *Tulipa sylvestris* (Bambacioni-Mezzetti, 1931). Instead of becoming arranged in two pairs, all the four megaspore nuclei remain at the micropylar end of the coeno-megaspore[2] and give rise to a group of six cells (one of which is to be interpreted as the egg) and two free nuclei. *T. tetraphylla* (Romanov, 1939) is similar except that in this case five cells are formed at the micropylar end and one at the chalazal end, leaving two free nuclei to function as polars.

Because of these variations in the development of the embryo sac and also in that of the endosperm, I was prompted to undertake a study of as many members of the Liliaceæ and allied families as could be available to me. The present work on *Albuca* will soon be followed by other papers, the last of which will include a discussion of the inter-relationships of the genera studied by me, as far as it may be possible with the help of the available data.

Material and methods

Some paraffin material of *A. Transvalensis*, belonging to the sub-family Scilloideæ, was very kindly sent by Dr. S. Krupko of Johannesburg to Prof. P. Maheshwari, who passed it on to me for investigation. Sections were cut at a thickness of 7 to 12 microns and stained in Iron-Hæmatoxylin.

Ovary and ovules

The ovary consists of three syncarpous carpels with axile placentation (Fig. 2). Septal nectaries are prominent and well-developed and the cells composing them become conspicuous by their larger size and greater affinity for stains. In the beginning they form a single layer but at the time of fertilisation two layers may be present (Fig. 3). After fertilisation the cells become vacuolate and lose their prominence. Further, one of the two layers may disorganise or the walls separating the two dissolve and disappear. Some of the hypodermal cells of the ovary wall become enlarged and show large raphides of calcium oxalate.

The ovules are anatropous and bitegmic (Figs. 4–7). The inner integument which forms the micropyle is two-layered and the outer is three-layered. In older stages the swollen tips of the inner integument form a kind of "operculum" (Fig. 9) while the lower portion is gradually flattened and crushed due to the pressure exerted upon it by the enlarging embryo sac. A conspicuous annular swelling appears at the base of funiculus and its cells become glandular (Fig. 7). It seems likely that these glandular cells serve to nourish the pollen tubes for they disorganise

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[2] This term is applied to the cell containing the free megaspore nuclei formed after the meiotic divisions (see Fagerlind, 1944 ; Maheshwari, 1948).

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Fig. 2. T. S. of ovary showing three septal nectaries. × 26.
Fig. 3. Enlarged view of septal nectary. × 330.

soon after fertilization is over. The cells of nucellus are all thin-walled but those at the micropylar end become radially elongated and are more prominent than the rest. In younger stages the nuclei of the cells of nucellar epidermis lie towards the outer tangential walls of the cells (Fig. 8) but later they move towards the inner walls (Fig. 7). During the development of the embryo sac most of the nucellar tissue is gradually consumed but the cells of the nucellar epidermis and the chalaza persist for a long time.

Megasporogenesis

Normally there is a single hypodermal archesporial cell but in some ovules two and three archesporial cells have also been observed. The archesporial cell divides to produce a primary wall cell and the megaspore mother cell (Fig. 10). The former divides periclinally and anticlinally to form two wall layers (Fig. 12) of which the inner disorganises in later stages. The cells of the outer wall layer undergo some radial elongation but during the maturation of embryo sac they also disorganise and disappear.

Figs. 4, 5, 6, 7. L. S. ovules at progressively older stages of development. × 175.

Fig. 7. L. S. older ovule showing glandular swelling at the base of the funiculus. × 175.

Fig. 8. L. S. upper part of ovule at four-nucleate embryo sac stage showing the radially elongated cells of the nucellar epidermis. × 450.

Fig. 9. L. S. upper part of ovule showing the "operculum." × 450.

Fig. 12 shows a megaspore mother cell at the synizetic stage and Fig. 11 shows two megaspore mother cells lying in the same row. Fig. 13 shows two megaspore mother cells in the anaphase of the first reduction division. At the conclusion of the division two dyad cells are formed which divide again to give rise to the four megaspores. Normally the megaspores are arranged in a T-shaped manner (Figs. 14, 17) but linear tetrads are also common (Fig. 15). Fig. 16 shows a tetrad with the two upper megaspores arranged obliquely.

As usual the chalazal megaspore functions (Fig. 17). Fig. 18 shows a two-nucleate embryo sac with a large vacuole in the middle separating the two nuclei. This is followed by the four-nucleate stage (Fig. 19). Fig. 20 shows an abnormally large four-nucleate embryo sac. In the ovary, in which this embryo sac was found, all the other embryo sacs had already reached maturity. The nuclei of the four-nucleate embryo sac undergo another division to produce eight nuclei (Fig. 21). Three of these organise into the egg apparatus, three form antipodal cells and the remaining two unite to form the secondary nucleus (Fig. 22).

In the synergids the nucleus lies at the lower and broader end of the cell (Fig. 22) which is contrary to the usual condition in angiosperms. Further, the cytoplasm of the synergids is denser than that of the egg and takes a heavier stain. One of the synergids persists for some time after fertilisation and is quite conspicuous even at the two-celled stage of the embryo (Figs. 26, 29). At the time of fertilisation it is often larger and more prominent than the egg so that at the first sight it is mistaken for the latter.

Of the antipodal cells the basal becomes elongated and projects downward into the nucellar cells at the chalazal end of the embryo sac. Apparently it helps in the conduction of food materials into the embryo sac. The other two antipodal cells are broader at the upper end and contain a large vacuole in this region, while the narrow basal end contains the nucleus and most of the cytoplasm (Fig. 23). Later, all the antipodal cells show a denser cytoplasm and take a deeper stain (Figs. 24, 25).

Fertilization

The pollen tube enters the embryo sac through the micropyle and destroys one of the synergids. One male gamete unites with the egg and the other with the secondary nucleus.

Endosperm

The endosperm is of the Helobial type. The primary endosperm nucleus moves downward and divides just above the antipodal cells. The two nuclei produced by this division become separated by a wall (Fig. 28). The nucleus of the micropylar chamber undergoes many free nuclear divisions and the daughter nuclei become scattered along the periphery of the embryo sac, but only a few divisions take place in the chalazal chamber (Figs. 27, 29). It has been observed that when the nucleus of the chalazal chamber is in the first metaphase, that of the micropylar has already completed its division and the two daughter nuclei are widely separated from each other. When the number of nuclei

Fig. 10. Megaspore mother cell and primary wall cell. × 525.
Fig. 11. Two megaspore mother cells one lying above the other. × 450.

Fig. 12. Megaspore mother cell at the synizesis stage with two layers of wall cells. × 450.
Fig. 13. Megaspore mother cell in the anaphase of the first reduction division. × 450.
Fig. 14. T-shaped tetrad of megaspores. × 450.
Fig. 15. Linear tetrad of megaspores. × 450.
Fig. 16. Tetrad showing oblique arrangement of the two upper megaspores. × 450.
Fig. 17. Functioning megaspore with remains of the degenerating megaspores. × 450.
Fig. 18. Binucleate embryo sac. × 450.
Fig. 19. Four-nucleate embryo sac. × 450.
Fig. 20. An abnormally large four-nucleate embryo sac. × 450.
Fig. 21. Eight-nucleate embryo sac. × 450.
Fig. 22. Fully organised embryo sac ; note that the nucleus in the egg as well as the synergids lies in the basal part of the cell. × 450.

in the chalazal chamber is two or four the micropylar chamber shows four, eight or sixteen nuclei.

Embryo

The first division of the oospore is transverse and it takes place after the division of the primary endosperm nucleus. The two-celled pro-embryo consists of a large basal cell and a small terminal cell (Fig. 26). Older stages were not available in the material at my disposal.

Conclusion

Formerly the Scilloideæ formed a part of the Lilioideæ which were subdivided into the Tulipeæ (*Lilium*, *Fritillaria*, *Erythronium*, *Tulipa*, *Lloydia*, etc.) and Scilleæ (*Urginea*, *Albuca*, *Scilla*, *Muscari*, *Hyacinthus*, etc.). Schnarf's investigations led to the separation of the Scilleæ and the erection of a new sub-family, the Scilloideæ. The present study as well as my work on *Fritillaria* (Eunus, 1949) support this view. The differences between the Lilioideæ (=Tulipeæ) and the Scilloideæ may be tabulated as follows (Wunderlich, 1937) :—

Lilioideæ.	*Scilloideæ.*
1. Wall cell absent. Megaspore mother cell lies directly below the epidermis.	1. Wall cell present. Megaspore mother cell separated from epidermis by a wall cell.
2. Embryo sac of the Fritillaria type.	2. Embryo sac of the Polygonum or Allium type
3. Endosperm Nuclear.	3. Endosperm Helobial.
4. Embryo small.	4. Embryo large and reaching nearly to the base of the seed.
5. Pollen grains large ; generative cell broadly spindle-shaped.	5. Pollen grains smaller ; generative cell narrow and elongated.
6. Male gametes elongated.	6. Male gametes spherical.
7. Raphides absent.	7. Raphides present.
8. Septal nectaries absent.	8. Septal nectaries present.

My material of *Albuca* did not enable me to study the development of the male gametophyte and embryo but in all other respects it corresponds with the conditions prevailing in the Scilloideæ. Septal nectaries

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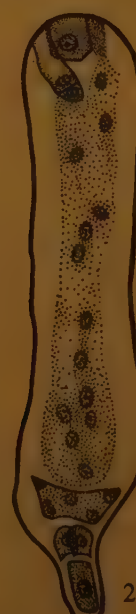

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Figs. 23, 24, 25. Lower part of embryo sac showing increasing density of cytoplasm in the antipodal cells ; note secondary nucleus lying above antipodal cells in Figs. 23, 24. × 450.

Fig. 26. Micropylar portion of embryo sac showing two-celled proembryo and a persisting synergid. × 450.

Fig. 27. L. S. ovule showing Helobial endosperm ; note constriction in middle region of embryo sac. × 60.

Fig. 28. Embryo sac after completion of the first division of the primary endosperm nucleus. × 77.

Fig. 29. Embryo sac showing persisting synergid, two-celled proembryo, and Helobial endosperm. × 77.

are prominent and well-developed ; the megaspore mother cell is separated from the nucellar epidermis by a wall cell ; there is a tetrad of megaspores of which the chalazal functions to give rise to an eight-nucleate embryo sac ; the endosperm is Helobial ; and raphides are present.

A noteworthy feature of *Albuca* is the structure of the synergids whose cytoplasm is denser than that of the egg and in which the nucleus lies towards the lower end of the cell rather than the upper. Further, one of the synergids persists until some time after fertilization and seems to serve a haustorial function. This condition is similar to that in some species of the genus *Allium* belonging to the Allioideæ (Weber, 1929). In *Allium senescens* and *A. victoriale* the synergids disappear soon after fertilization. In *A. flavum*, *A paniculature*, *A ursinum* and *A. zebdanense* they are weakly hypertrophied and provide nutrition to the zygote. In *A. unifolium* and *A. rotundum* one synergid remains active until the embryo is several-celled. In *A. rotundum* and *A. zebdanense* the synergid may itself give rise to an embryo.

Prominent synergids also occur in the sub-family Scilloideæ, as in *Muscari* (Wunderlich, 1937), but the condition is not so marked as in *Albuca*.

Regarding the systematic position of the genus *Albuca* within the sub-family Scilloideæ, its natural place lies with *Muscari*, *Ornithogalum*, *Puschkinia*, *Heloniopsis* and *Veratrum* which are characterised by a Helobial endosperm, rather than with *Scilla*, *Hyacinthus*, *Camassia* and *Galtonia* which have a nuclear endosperm.

Summary

1. The ovule is anatropous and bitegmic. The inner integument forms the micropyle. In later stages its swollen tips give rise to an " operculum ".

2. Septal nectaries are present. The cells at the base of funiculus enlarge and form a annular swelling.

3. Usually there is a single hypodermal archesporial cell but in some cases two and three archesporial cells have also been seen. The archesporial cell divides to form a megaspore mother cell and a wall cell. The latter divides periclinally to give rise to two wall layers but they degenerate and disappear during the maturation of the embryo sac.

4. The cells of the nucellar epidermis are markedly elongated in the micropylar region. In pre-fertilisation stages their nuclei lie towards the periphery but later they move down towards the lower tangential wall.

5. Both T-shaped and linear tetrads are formed. The chalazal megaspore functions.

6. The embryo sac is of the monosporic eight-nucleate type. In the synergids the nucleus occurs towards the lower end of the cell and the vacuole towards the upper.

7. The endosperm is of the Helobial type.

In conclusion I think it my duty to express my sincerest gratitude to Drs. P. Maheshwari and B. M. Johri for their guidance and interest

throughout the course of this investigation. Thanks are also due to Dr. S. Krupko of the University of Johannesberg who kindly supplied the material.

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A CONTRIBUTION TO THE LIFE HISTORY OF *OTTELIA ALISMOIDES* PERS.[1]

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(*Received for publication on September* 17, 1949).

Introduction

The family Hydrocharitaceae has attracted considerable attention from morphologists and embryologists, and several genera have been studied in fair detail, viz., *Vallisneria*, *Elodea*, *Enalus*, *Hydrilla*, *Halophila* and *Ottelia*. Among the earlier investigations that of Wylie (1904) on *Elodea canadensis* is the most important. The common pondweed, *Vallisneria*, has been studied by Burr (1903), Rangasamy (1934) and Witmer (1937), and the last-named author has made a thorough investigation of almost all stages of the life history of this plant. Wylie (1917, 1923, 1941) has studied the mechanism of pollination, structure of the male gametes, and some aspects of fertilization ; and Kausik (1939) and Svedelius (1932) have described the mode of pollination in *V. spiralis* and *V. americana* respectively. Svedelius (1904) and Kausik (1940, 1941) have also studied the life history of *Enalus acoroides* and Kausik and Rao (1942) have described the development of the male gametophyte in *Halophila ovata*. A detailed work on the life history of *Hydrilla verticillata* has been undertaken by Maheshwari and Johri and some preliminary observations on this plant have already been published by Maheshwari (1933, 1934). *Ottelia alismoides*, the study of whose life history forms the subject of the present investigation, and *Ottelia lancifolia* have been partially studied by Narasimha Murthy (1935) and Palm (1915) respectively.

Material and methods

Although *Ottelia alismoides* has been previously studied, some of Narasimha Murthy's observations appear to be doubtful (see Maheshwari, 1943) and hence it was felt desirable to reinvestigate this plant with a view to checking upon his findings.

The plant flowers abundantly during the rainy season in the ponds and drains of Bengal. The material was fixed and imbedded as usual. Ovaries were cut longitudinally at 10μ and root tips were cut transversely at 12μ. Some of the slides were stained in iron alum Haematoxylin and others in Safranin and Fast Green. The material proved to be particularly easy to cut and stain and is recommended for illustrating all phases of development of the gametophytes, endosperm and embryo to elementary classes in botany.

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[1] A preliminary account of this work appeared in the Proceedings of the Indian Science Congress, 36th session at Allahabad (Islam, 1949).

Development of anther

There are six short-stalked stamens. Extreme reduction in the length of the filament is also seen in other genera of this family, e.g., *Vallisneria*, *Enalus* and *Halophila*; and in *Elodea canadensis* the anthers are almost sessile (Wylie, 1904). In *Ottelia* each anther shows four loculi (very rarely five, as in the anther at the lower left side in Fig. 1) ; in *Elodea canadensis* these are two (Wylie, 1904) and in *Vallisneria spiralis* the number varies from one to four (Witmer, 1937). The archesporial cells are hypodermal and divide periclinally to give rise to the primary parietal layer and the primary sporogenous tissue. By further periclinal and anticlinal divisions the primary parietal layer gives rise to three layers of cells of which the innermost becomes differentiated as the tapetum, the next as a middle layer, and the outermost as the endothecium. Apparently the presence of the middle layer is not a constant feature in this family. It is said to be absent in *Elodea canadensis* (1904) and *Vallisneria spiralis* (1937). What Kausik (1942) describes in *Halophila ovata* as the middle layer also seems to be the thickened endothecium. In *Ottelia* the middle layer begins to collapse soon after its formation and is no longer recognisable in the mature anther. The tapetal cells are uninucleate with abundant cytoplasm. During the meiotic divisions of the microspore mother cells they begin to lose contact with one another. By the time tetrad formation is complete their walls break down and the nuclei and cytoplasm protrude into the loculus (Fig. 5). The formation of a tapetal periplasmodium is quite common in the order Helobiales and has been reported in the Hydrocharitaceae in *Hydrilla verticillata*, *Vallisneria spiralis*, *Elodea canadensis* and *Enalus acoroides*. The periplasmodium is completely used up by the developing microspores so that at the shedding stage of the pollen there is no trace of the nuclei or cytoplasm of the tapetal cells. The fibrous thickenings characteristic of the endothecium of other plants are absent in this family which is probably related to the aquatic habit of these plants.

Microspore formation

With the initiation of the prophase of the meiotic division, the microspore mother cells pass into the so-called synizetic stage. This stage has also been described by Rangasamy (1934) in *Vallisneria* and by Narasimha Murthy (1935) in *Ottelia*. Whether such a stage actually precedes the leptotene stage or whether it is an artefact caused by improper fixation cannot be said with certainty[2]. In the leptotene stage the chromonemata are scattered inside the nucleus. The other stages from the microspore mother cell to the formation of tetrad were not available in my material.

The tetrads are usually isobilateral (Fig. 2) as in most Monocotyledons, but linear tetrads also occur sometimes (Fig. 4). Further, several gradations were seen between these two types one of which is shown in Fig. 3. This variation in the arrangement of microspores in the

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[2] Darlington (1937) and Sharp (1947) make no mention of the synizetic stage in their account of meiotic division.

tetrad has also been seen in *Vallisneria spiralis* (Witmer, 1937). In *Halophila ovata* the tetrads are always linear (Kausik and Rao, 1942).

Approximately 40 to 50 per cent of the microspores degenerate which is probably due to an unequal distribution of the chromosomes to the two poles during the first meiotic division. This assumption is based on Fig. 7 of Narasimha Murthy which shows several lagging chromosomes at the anaphase stage of the first meiotic division. These lagging chromosomes probably fail to be included within the dyad nuclei thus upsetting the chromosome balance and resulting in the degeneration of a large percentage of pollen grains (Bhaduri and Islam, 1949). A fully developed microspore shows a well developed exine which is not smooth as figured by Narasimha Murthy but studded with minute spines.

Male gametophyte

A young microspore shows a prominent nucleus imbedded in dense cytoplasm. Soon a large vacuole appears in the centre and the nucleus is pushed towards one side. The first division of the microspore (Fig. 6) gives rise to the vegetative and generative cells. All stages in this division were available and counts made at the metaphase stage showed that the haploid number of chromosomes is 22. At the end of the telophase an ephemeral cell plate is laid down separating the vegetative and generative nuclei (Fig. 7). Very soon, however, the generative cell moves from its original position and may come to lie in any part of the pollen grain. During this process it grows to a large size and assumes a crescent-shaped appearance. In later stages it extends across the entire width of the pollen grain with its pointed ends touching the intine (Fig. 8). As the pollen grain reaches maturity, its cytoplasm becomes denser and there is no conspicuous vacuolation at the shedding stage. *Ottelia* is an exception in having two-celled pollen grains for in all other plants of the family the generative cell divides within the pollen grain to form the two male cells[3]. In fact all the families of the order Helobiales show three-celled pollen grains, the only other exception being *Zannichellia palustris* (Campbell, 1897).

For a study of the division of the generative cell pollen grains were germinated on slides having a thin layer of dextrose agar. The pollen tubes were fixed and stained with acetocarmine but details of the division of the generative cell were not very clear as the cytoplasm and the chromosomes stained with almost equal intensity.

Ovary and ovules

Although a detailed discussion on the nature of the gynæcium is beyond the scope of the present paper, a brief reference to the subject will not be out of place. Doubt has been expressed by Troll (1931) about the syncarpous nature of the ovary; yet the fact remains that all the carpels are enclosed within a common ovarian wall and in the earlier stages each

[3] Palm (1915) suggests a possibility of the occurrence of three-nucleate pollen grains in *Ottelia* but this could not be confirmed by me.

carpel is in intimate con tact with its neighbour. The ovary is partitioned imperfectly into either six (Fig. 9) or nine loculi (Fig. 10) depending upon the number of carpels, and each partition wall is composed of the laminæ of two adjacent carpels. Each carpel has a supply of three vascular bundles, one situated at its midrib and the other two on the two sides. However, owing to a fusion of the lateral bundles of juxtaposed carpels the total number of vascular bundles is only twice the number of carpels. During the maturation of the ovary each partition wall splits at the tip (Fig. 9) along the original line of union and the split gradually extends centrifugally till the laminæ of the carpels become completely separated. Air spaces gradually appear in the laminæ and also extend to the ovary wall. Probably they help to maintain the buoyancy of the fruit. The placentation is laminar and the ovules are anatropous and bitegmic. The micropyle is formed by both integuments.

Megasporogenesis

Except in the families Alismaceæ and Butomaceæ the cutting off of a parietal cell by the archesporium is a common feature in the order Helobiales[4]. Narasimha Murthy's report that in *Ottelia* the archesporial cell functions directly as the megaspore mother cell was found to be incorrect. A parietal cell is cut off by the archesporial cell and divides anticlinally to produce two wall cells (Figs. 15, 16). Narasimha Murthy (1935) reported the presence of a multicellular archesporium but in my material I have found a maximum of two megaspore mother cells in a nucellus (Fig. 25). The first division of the mother cell is heterotypic as was evidenced by the nature of pairing of the homologous chromosomes. Of the two dyad cells (Fig. 17) only the chalazal divides (Fig. 18) and thus a row of three cells is produced instead of usual four (Fig. 19). The number and arrangement of the megaspores vary in different members of the Hydrocharitaceae. In *Elodea canadensis* (Wylie, 1904) the megaspore mother cell is said to produce six megaspores but it seems that one of the cells in his Fig. 28 is really a second and undivided megaspore mother cell, as in *Ottelia* in which I have observed a second and undivided megaspore mother cell arranged in the same row with the chalazal functioning megaspore and the other degenerating cells (Fig. 26). In *Vallisneria spiralis* (Witmer, 1937) the tetrads may be linear, T-shaped, or tetrahedral. A tetrahedral arrangement is also seen in *Enalus acoroides* besides the usual linear type (Kausik, 1940). Palm (1915) and Narasimha Murthy (1935) report the formation of four megaspores in *Ottelia lancifolia* and *O. alismoides* respectively, but I have seen only a row of three cells caused by a failure of division of the upper dyad cell (Fig. 19). The possibility of the occurrence of a tetrad cannot however be ruled out. In any case the chalazal megaspore alone functions and forms a normal eight-nucleate embryo sac by three successive divisions (Figs. 21, 22, 23). The micropylar end of the embryo sac widens out while the chalazal end remains comparatively narrower.

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[4] Kausik (1941) has erroneously stated that the parietal cell is of universal occurrence in the order Helobiales.

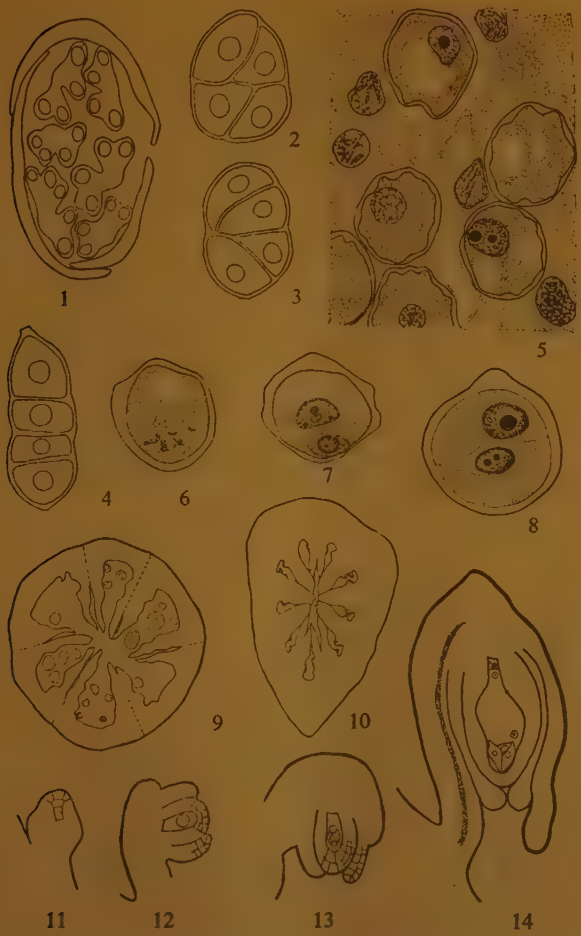

Fig. 1. T. S. young bud passing through anthers and inner whorl of perianth. One anther (*bottom left*) shows five pollen sacs. × 23.

Figs. 2-4. Different kinds of microspore tetrads showing isobilateral and linear arrangement of microspores in figs. 2 and 4 respectively and an intermediate form in fig. 3. × 240.

Fig. 5. L. S. portion of anther locule showing tapetal periplasmodium. × 373.

Fig. 6. Division of the microspore nucleus.

Fig. 7. Pollen grain showing vegetative and generative cells.

Fig. 8. Mature pollen grain showing elongated generative cell. × 373.

Fig. 9. T. S. ovary showing 6 parietal placentæ projecting into the loculus. The broken lines indicate the limits of each carpel. × 7.

Fig. 10. T. S. young ovary showing 9 placentæ projecting into the loculus ; their inner ends are in close contact. The shaded portions represent the primordia of the ovules. × 23.

Figs. 11-14. L. S. ovules at progressively older stages of development. × 106.

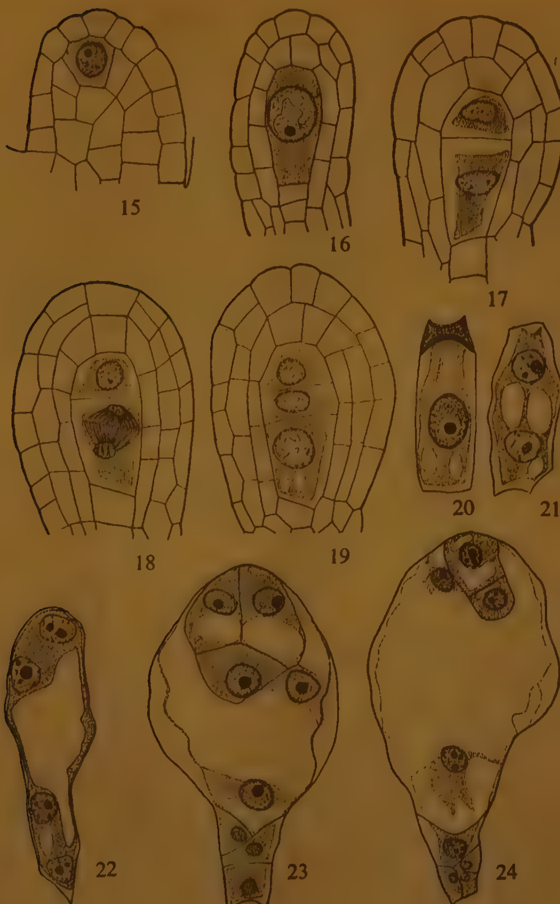

Fig. 15. L. S. young ovule showing hypodermal archesporial cell. × 373.

Fig. 16. Megaspore mother cell with two wall cells. × 373.

Fig. 17. Dyad cells formed after first division of the megaspore mother cell. Note periclinal division in some cells of the nucellar epidermis. × 373.

Fig. 18. Chalazal dyad cell in telophase of second meiotic division ; the upper dyad cell remains undivided. × 373.

Fig. 19. The two megaspores and the upper dyad cell. × 373.

Fig. 20. The functioning chalazal megaspore with remains of the degenerating cells. × 373.

Figs. 21-22. Two- and four-nucleate stages of embryo sac. × 373.

Fig. 23. Fully developed eight-nucleate embryo sac showing egg apparatus, two polar nuclei and three antipodal cells. × 373.

Fig. 24. Mature embryo sac with two-celled proembryo and Helobial endosperm. The persisting antipodal cells are seen at the chalazal end. × 240.

This unequal growth at the two ends of the embryo sac gives it a pear-shaped appearance. The egg apparatus is organized as usual. The two synergids have a large vacuole at the basal end (Fig. 23). Narasimha Murthy's statement that " both the synergids are bent in a concave manner " and " form a chamber in which the egg is suspended " could not be confirmed. The polar nuclei are of approximately the same size and lie wide apart, one in close proximity to the egg apparatus and the other to the antipodal cells (Fig. 23). The nuclei of the antipodal cells are much smaller than the other nuclei of the embryo sac (Fig. 23). Although small and feeble the antipodals are recognizable for a considerable time after fertilization.

The flowers are protandrous and microspore formation is completed before the megaspore mother cell is ready for reduction division. The following table gives the comparable stages in development of anther and ovule.

Stages in development of anther.	*Stages in development of ovule.*
1. Microspore mother cells well differentiated.	Archesporium not distinguishable.
2. Tetrad of microspores.	Differentiation of hypodermal archesporial cell.
3. Microspore.	Formation of primary parietal cell and megaspore mother cell.
4. Formation of tube and generative cells.	Divisions of megaspore mother cell.

Fertilization

The pollen tube stains very densely and is therefore easily recognisable. One of the synergids is destroyed during its entry into the embryo sac. The gametes are not vermiform as in *Lilium* (Mottier, 1898) but spherical and only half as large as the nuclei of the cells of the egg apparatus as also reported by Witmer (1937) in *Vallisneria*. After its entry into the egg cell the sperm fuses with the egg nucleus. In his study of *Vallisneria spiralis* Wylie (1941) reports that the male cytoplasm also takes part in the act of fertilization. Whether this is also true of *Ottelia alismoides* could not be ascertained by me. He also reports the entrance of a second pollen tube in the ovules but this was not observed in *Ottelia*. Sections stained with Safranin and Fast Green showed one or two red-stained bodies lying by the side of the egg. These are probably the disintegrated remains either of one of the synergids or of the tube nucleus and are similar to the X-bodies recorded in *Elodea* (Wylie, 1904) and *Vallisneria* (Witmer, 1937). It is the upper polar nucleus which always moves down and fuses with the lower polar nucleus and the second male nucleus. Narasimha Murthy's Fig. 21 shows all the three fusing nuclei to be of approximately the same size which is incorrect. As already stated the male nucleus is only half as large as either of the polar nuclei. In *Elodea* and *Vallisneria* (Wylie, 1904, 1941) the polar nuclei fuse first and then the secondary nucleus fuses with the male nucleus, but in *Ottelia* all the three nuclei fuse together.

A few pollen grains were found lying inside the ovary. Such an occurrence, although rare, has already been recorded previously in *Butomopsis* (Johri, 1936) and *Erythronium* (Haque, 1949). The style is hollow and apparently the pollen grains may be sucked down through it.

Endosperm

Narasimha Murthy (1935) states that the first division of the primary endosperm nucleus gives rise to two chambers of which the micropylar chamber is very large in the early stages. Later on, nuclear divisions follow in both the chambers and the micropylar chamber is said to become equalled in size by the chalazal chamber in consequence of the rapid growth of the latter. Maheshwari (1943) showed that this is incorrect and my observations which are in complete agreement with his, may be summarised as follows. The primary endosperm nucleus migrates to the basal part of the embryo sac and comes to lie just above the antipodals. The first division results in the formation of two chambers of very unequal size (Fig. 24). The nucleus of the primary chalazal chamber, which is much smaller, does not divide[5]. The nucleus of the micropylar chamber divides repeatedly resulting in a large number of free nuclei which become arranged peripherally. Palm (1915) observed occasional fusions of these nuclei in *Ottelia lancifolia* but I have not been able to confirm this in *O. alismoides*. Wall formation was not observed although its occurrence has been reported in some other genera of the Hydrocharitaceae, viz., *Vallisneria*, *Elodea* and *Enalus*.

The chalazal chamber stains densely and its nucleus becomes hypertrophied. With the continued growth of the embryo the antipodal cells as well as the chalazal chamber are eventually crushed and obliterated. At this stage a nucellar cell lying just below the place, formerly occupied by the antipodal cells, takes a deep stain with Safranin and Fast Green. Probably this cell takes over the haustorial function of the chalazal chamber after the latter has degenerated.

Embryo

The first division of the fertilized egg occurs just after the first division of the primary endosperm nucleus. Of the two cells (Fig. 24) the basal cell remains undivided and forms a large haustorium. The other cell divides transversely to produce a three-celled proembryo (Fig. 27). The middle cell of this stage divides transversely into two cells and the proembryo now consists of four cells arranged in a linear fashion. The terminal cell of the four-celled stage divides vertically (Fig. 28). At the next stage the proembryo consists of two juxtaposed cells at the apex and four cells arranged in a row (Fig. 30). Fig. 31 shows an embryo in which the subterminal cell has also divided vertically producing the quadrant stage[6]. With further divisions a large embryo is formed with a lateral stem tip and a terminal cotyledon (Figs. 31-34) which shows a well differentiated

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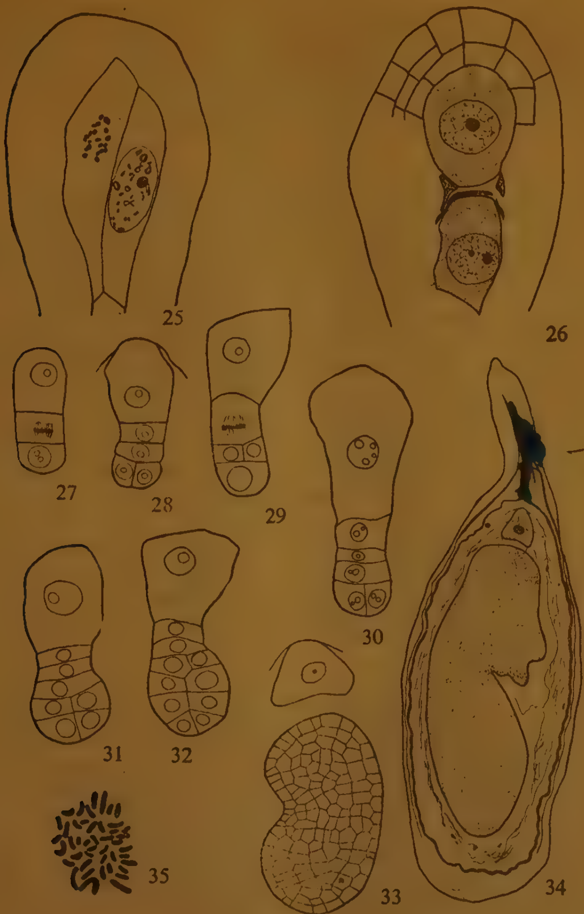
[5] In *Ottelia lancifolia* Palm (1915) has reported one or two divisions in the chalazal chamber.

[6] Occasionally the division of the terminal cell of the four-celled proembryo is delayed and is preceded by the anticlinal division of the subterminal cell (Fig. 29).



C.f.

Fig. 25. Two megaspore mother cells lying side by side. × 373.

Fig. 26. L. S. ovule showing an undivided megaspore mother cell, a functioning megaspore, and some cells between them. × 373.

Fig. 27. Three-celled proembryo with middle cell dividing.

Fig. 28. The terminal cell has divided by a vertical wall. × 240.

Fig. 29. The penultimate cell has divided by a vertical wall before division has taken place in the terminal cell. × 240.

Figs. 30-32. Further stages in development of the embryo ; note greatly enlarged basal cell. × 240.

Fig. 33. More advanced embryo. × 106.

Fig. 34. Diagrams of l.s. of nearly ripe seed showing lateral stem tip, terminal cotyledon, degenerating basal cell, and cuticular layer formed by the inner layer of the inner integument. × 57.

Fig. 35. Polar view of mitotic metaphase of a root tip cell showing 44 chromosomes. × 733.

procambial tissue. During this time, the endosperm nuclei and most of the nucellus are consumed. The basal cell has enlarged enormously and become vesicular. It is recognisable even in nearly mature seeds (Fig. 34), although the cells connecting the basal cell with the embryo proper seem to become crushed and obliterated at this stage.

Seed

Simultaneously with the development of the embryo the two integuments undergo profound changes. When the proembryo consists of about a dozen cells, the inner epidermis of the inner integument becomes heavily cutinized. At a slightly later stage, when the stem tip becomes differentiated in the embryo, the inner wall of the outer integument also becomes cutinized. However, in this case the cuticle is much weaker and becomes less distinct in older stages. Meanwhile the cells of the inner integument which are sandwiched between these two cutinized layers get crushed and obliterated. Only a few disintegrated remains of the nucellar cells separate the wall of the embryo sac from the inner cuticle (Fig. 34). The cells of the outer epidermis become greatly elongated and twisted so as to give the appearance of a plexus of intertwined hyphæ which fill up the empty spaces in the ovary between the seeds. Thus the seeds appear to be imbedded in a ground substance which is really formed by their own seed coats. In *Vallisneria* (Witmer, 1937), on the other hand the seed has a rough surface due to the development of protrusions from the tangential walls of the outer layer of the outer integument.

Somatic chromosomes

The number of somatic chromosomes, counted from root tip preparations, was found to be 44 (Fig. 35). This is in conformity with the number ($n = 22$) observed in the first division of the microspore nucleus. Narasimha Murthy (1935) reports the haploid number of chromosomes to be 36, basing his observations on dividing microspore mother cells. Darlington and Janaki Ammal (1945) report the diploid number to be approximately 40. My observations are therefore more in agreement with their findings than with those of Narasimha Murthy.

Discussion

A comparative study of all the plants of the Hydrocharitaceae as represented in the accompanying chart shows that *O. alismoides* differs in some important respects from the other plants of this family. The presence of four or in one case five microsporangia, the varied types of microspore tetrads ranging from the isobilateral to linear, two-celled pollen grains, the formation of a row of three cells instead of the usual tetrad of four megaspores and the peculiar development of the seed-coat are some of the features not met with in other plants of this family. The occurrence of pollen grains inside the ovary is another interesting feature which has not been reported in any other plant of this family.

In other respects, however, *Ottelia* shows a close resemblance with the rest of the Hydrocharitaceæ. There is practically no difference in

Summary of work done on the embryology of the Hydrocharitaceae.

Name of plant and author.	No. of pollen sacs in anther.	Wall layers in anther.	Tapetal periplasmodium.	Arrangement of microspores in tetrad.	Shedding stage of pollen grain.	No. of archesporial cells in an ovule.	Meg. m.c. and parietal cell.	Arrangement of megaspores in tetrad.	Embryo sac.	Double fertilisation.	Endosperm.	Embryo.
Blyxa echinosperma (Rangasamy, 1941)		Middle layer absent	Periplasmodium present	Linear or T-shaped	3-celled	One	Wall cell cut off	Linear or T-shaped	Polygonum type		Helobial type	Sagittaria type
Elodea canadensis (Wylie, 1904)	Two	Middle layer present	Periplasmodium present	Isobilateral	3-celled	Usually one	Wall cell cut off	Linear	Polygonum type	Occurs	Helobial type	Sagittaria type
Enalus acoroides (Kausik, 1940, 1941)	Four, with very short filaments	Middle layer present	Periplasmodium present	Isobilateral	3-celled	One	Wall cell cut off	Linear, sometimes tetrahedral	Polygonum type		Helobial type	Sagittaria type
Halophila ovata (Kausik and Rao, 1942)		Middle layer absent	Periplasmodium present	Linear	3-celled							
Ottelia alismoides (Islam, 1949)	Four, rarely five	Middle layer present	Periplasmodium present	Tetrahedral, isobilateral, linear	2-celled	Usually one, sometimes two	Wall cell cut off	Row of 3-cells	Polygonum type	Occurs	Helobial type	Sagittaria type
Vallisneria spiralis (Witmer, 1937)	1, 2, or 4 groups of sporogenous cells	Middle layer absent	Periplasmodium present	Tetrahedral and isobilateral	3-celled	One	Wall cell cut off	Linear, T-shaped or tetrahedral	Polygonum type	Occurs	Helobial type	Sagittaria type

the method of formation of periplasmodium, in the structure of the endothecium characterised by the lack of fibrous thickenings, in the nature of the ovules, in the cutting off of a wall cell by the archesporium and in the development of embryo sac, endosperm and embryo.

Summary

1. The stamens are short-stalked and the anthers are four-lobed (five-lobed in one case) with one group of sporogenous cells in each lobe. The primary parietal layer forms the endothecium, a middle wall layer and the uninucleate tapetum. The endothecium does not show any fibrous thickenings. The tapetal cells form the periplasmodium. The microspores show an isobilateral or linear or an intermediate arrangement.

2. The archesporial cell divides transversely to produce a wall cell and the megaspore mother cell. The meiotic divisions result in the formation of a row of three cells of which the upper is an undivided dyad.

3. Two archesporial initials or two megaspore mother cells also occur in some ovules.

4. The embryo sac is of the monosporic eight-nucleate type. The polar nuclei and the second male nucleus fuse simultaneously.

5. The endosperm is of the Helobial type. The nucleus of the chalazal chamber remains undivided. Free nuclear divisions take place in the micropylar chamber but are not followed by wall formation.

6. The embryo is of the Sagittaria type. The remnants of pollen tubes are traceable even in the ovules with well developed embryos or nearly ripe seeds.

7. Pollen grains were sometimes observed inside the ovary.

8. The somatic chromosome number is 44.

I offer my heartfelt gratitude to Prof. P. Maheshwari who supplied most of the slides and under whose guidance I carried out the present investigation. I am also indebted to Mr. R. Khan and Dr. B. M. Johri, University of Delhi, for their help and valuable suggestions.

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Printed by E. W. Dixon at The Times of India Press, Bombay, India, published by Professor S. P. Agharkar, Business Manager, Indian Botanical Society, Law College, Poona 4, for The Indian Botanical Society.